Fluoroscopy

- # Definition
  - Use of x-rays to produce a dynamic sequence of images ,which are viewed in real time

Types:

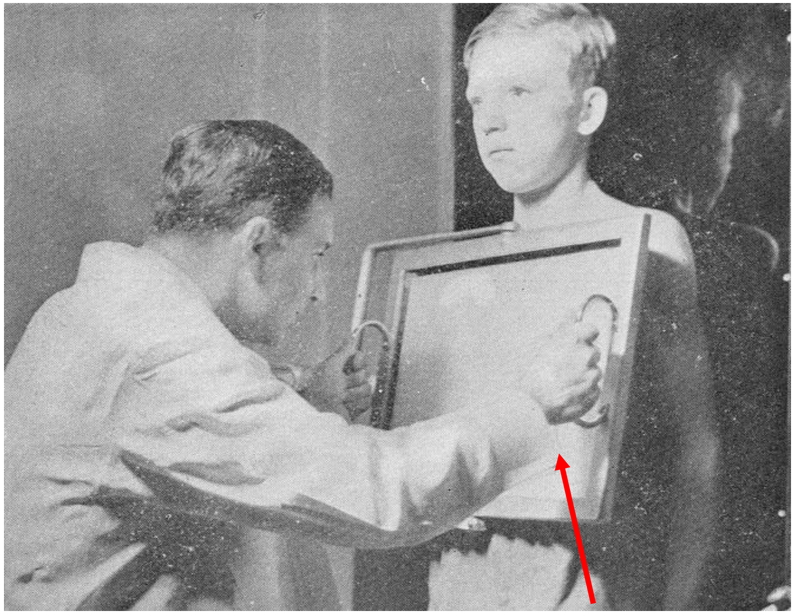
-Direct viewing fluoroscopy

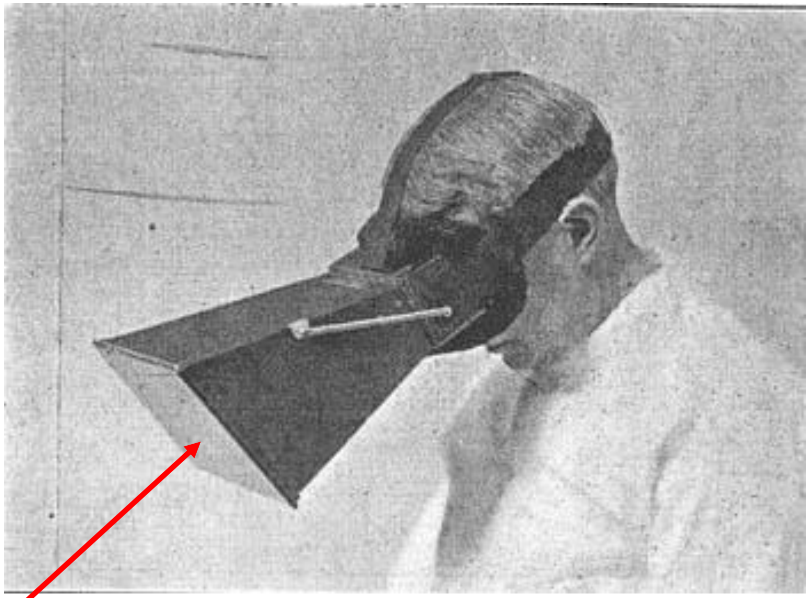
-Image intensifier

-Flat panel systems

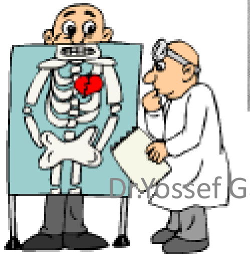
1) Direct viewing fluoroscopy

- Oldest fluoroscopy
- Radiology directly viewed using zinc sulphide fluorescent screen
- screen backed with lead glass for protection
- Limitation: dim image
  - Must be carried in dark room, with very low contrast images (rods =scotopic vision)

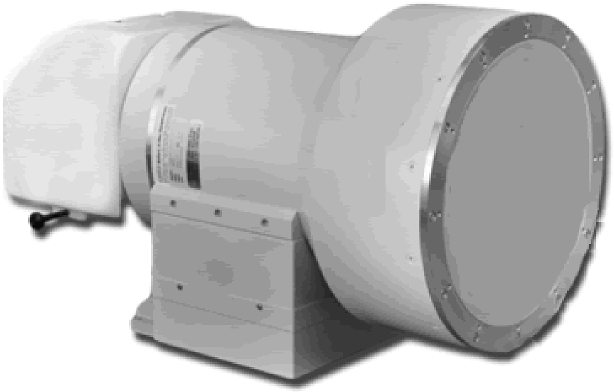


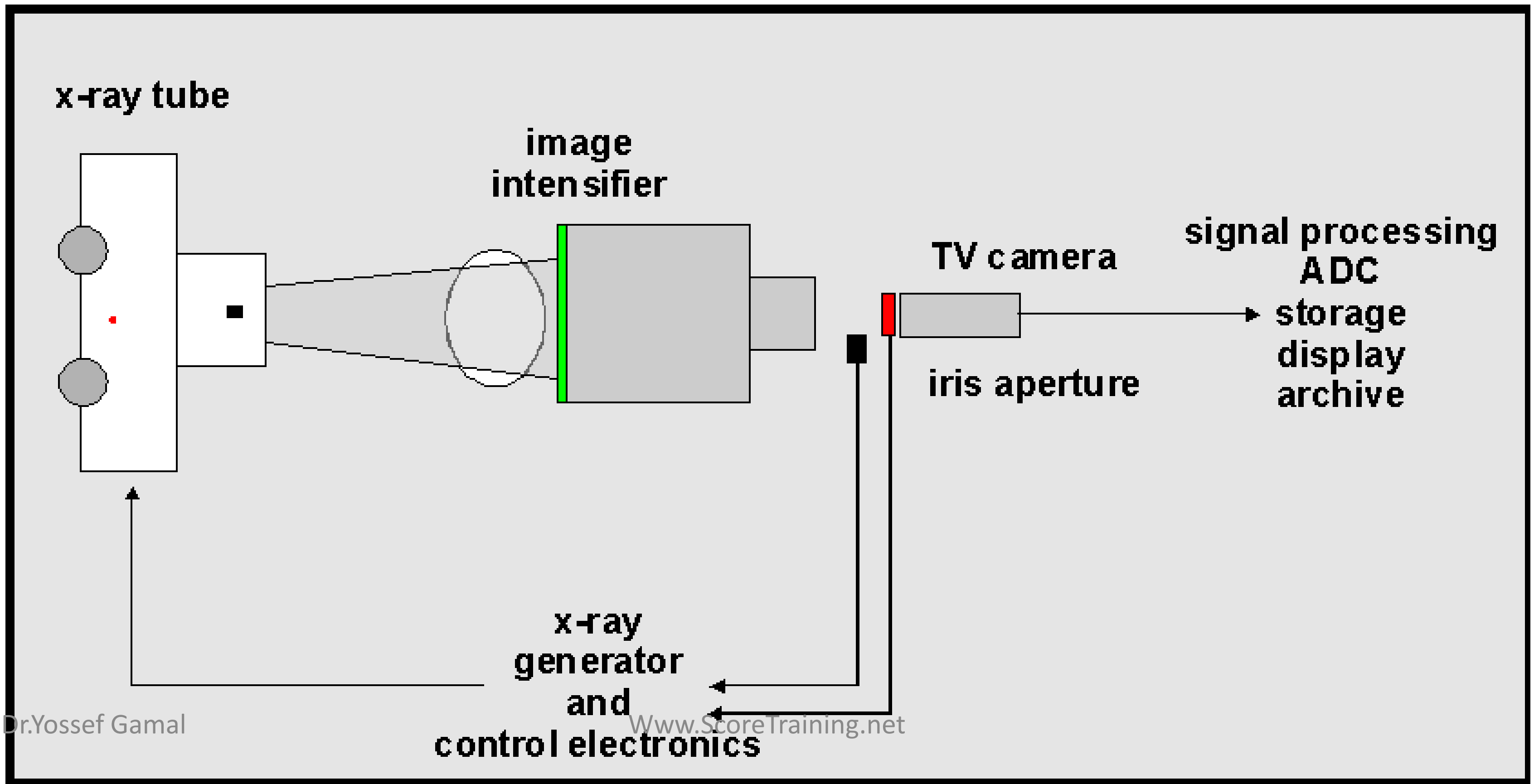


Fluorescent screen

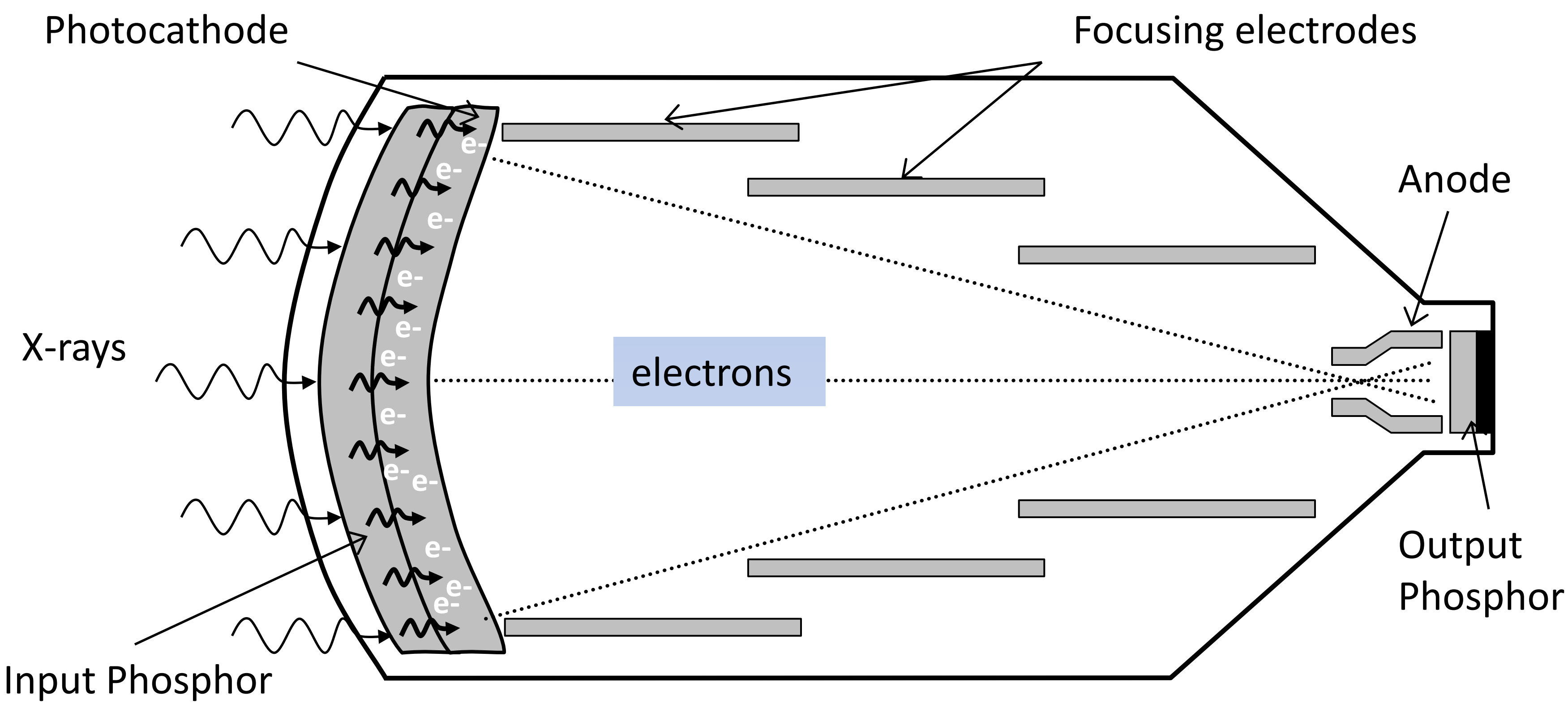


2)Image intensifier





The Image Intensifier



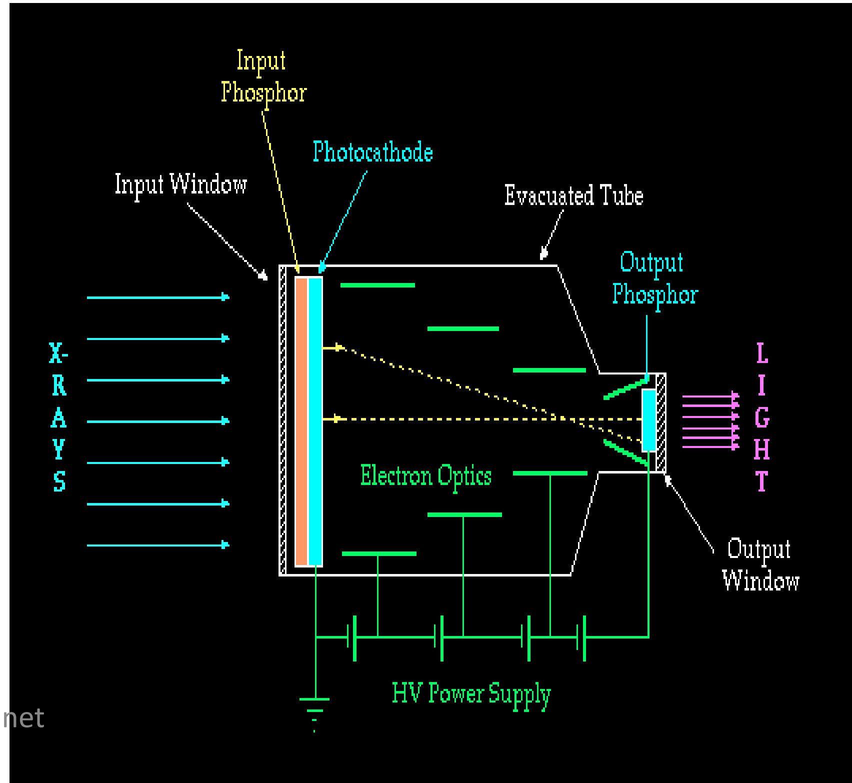
- Components of image intensifier:

1- Glass or ceramic envelope surrounded by metal housing:

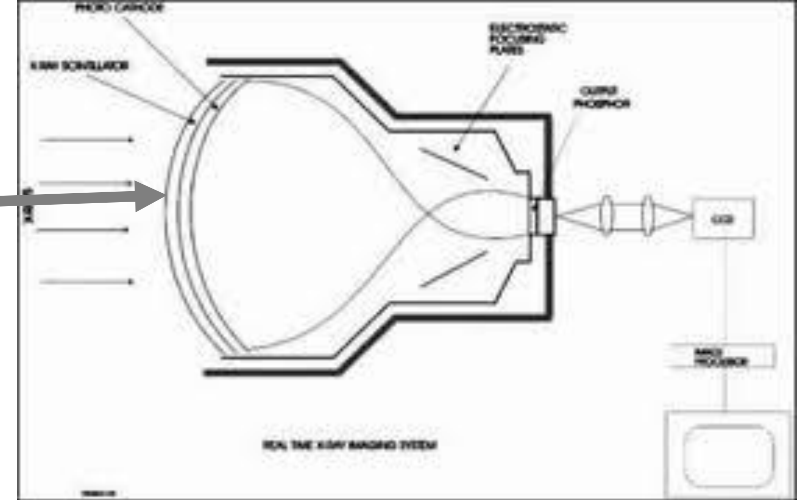
Function :

A) Prevent light from getting in the tube

B) Shield the device from magnetic field



2- Input screen :



- Consists of:

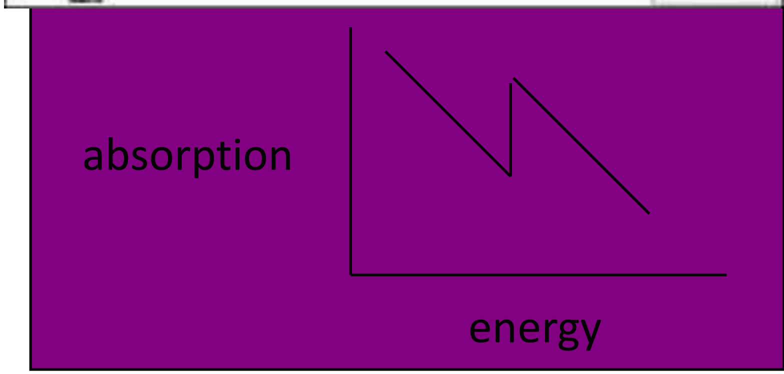
A) Input phosphor layer:

-Laid down in a thin metal layer

-At the outer (X-ray beam) side of the input screen

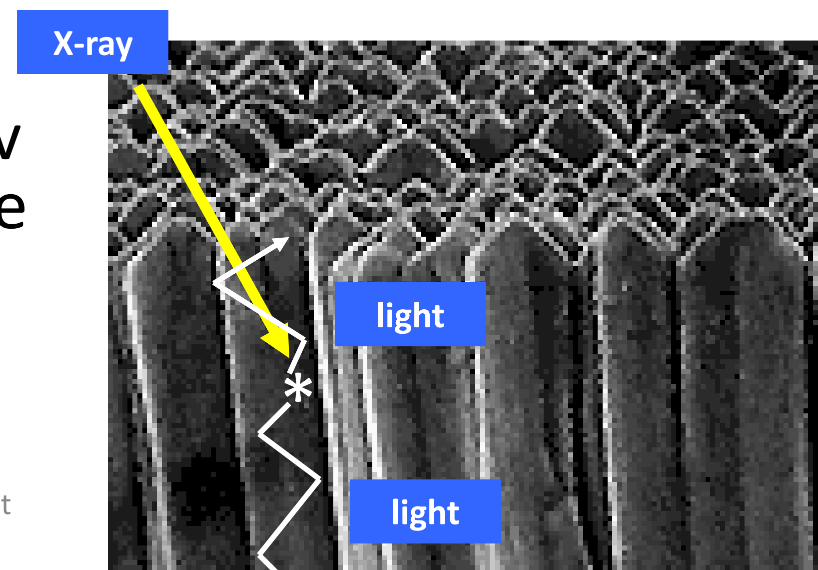
-Always: cesium iodide

-Advantages:



- ❑ High absorption efficiency (About 60% of the X-ray photons in 0.1-0.4 thick phosphor layer)

Because k-edge of cesium = 36 kev , and I = 33 kev (just below the used effective energy)

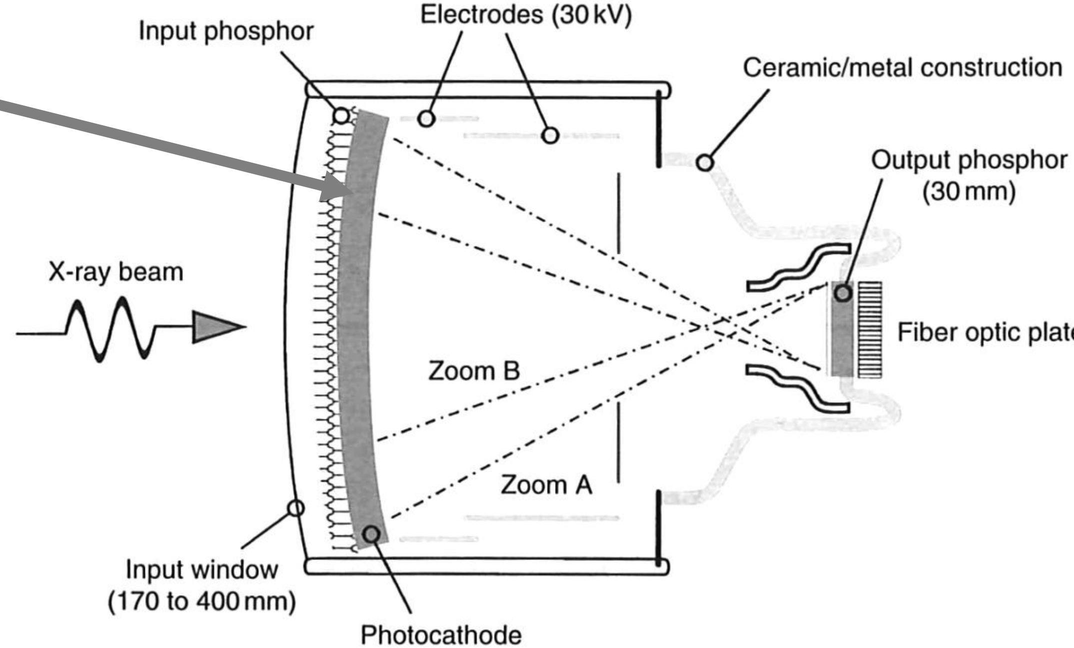


- ❑ Low unsharpness with thicker phosphors (why?)

Input screen (cont.)

- Size: 150 – 400 mm in diameter
- Smallest for fracture fixation
- Largest for angio

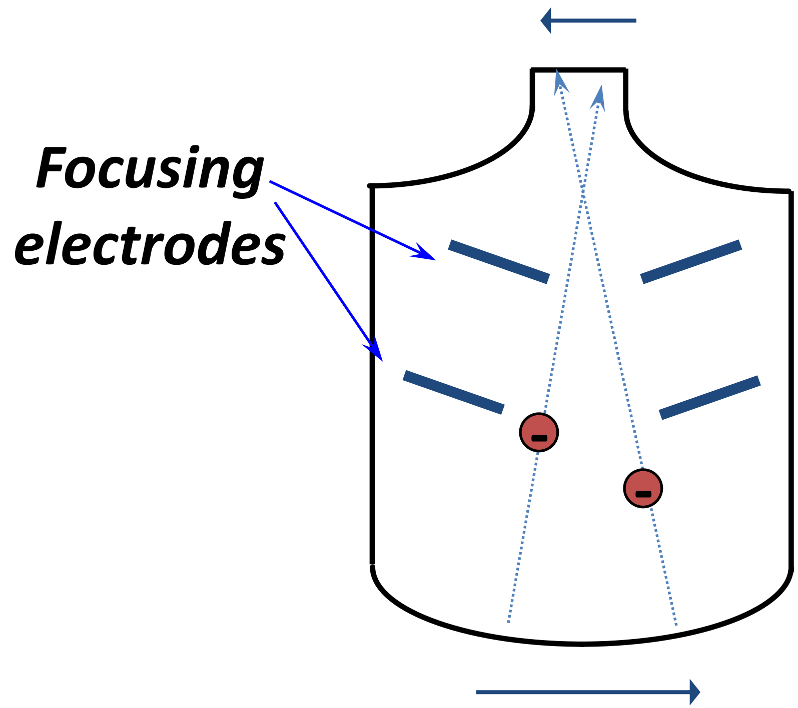
3) <u>photocathode:</u>

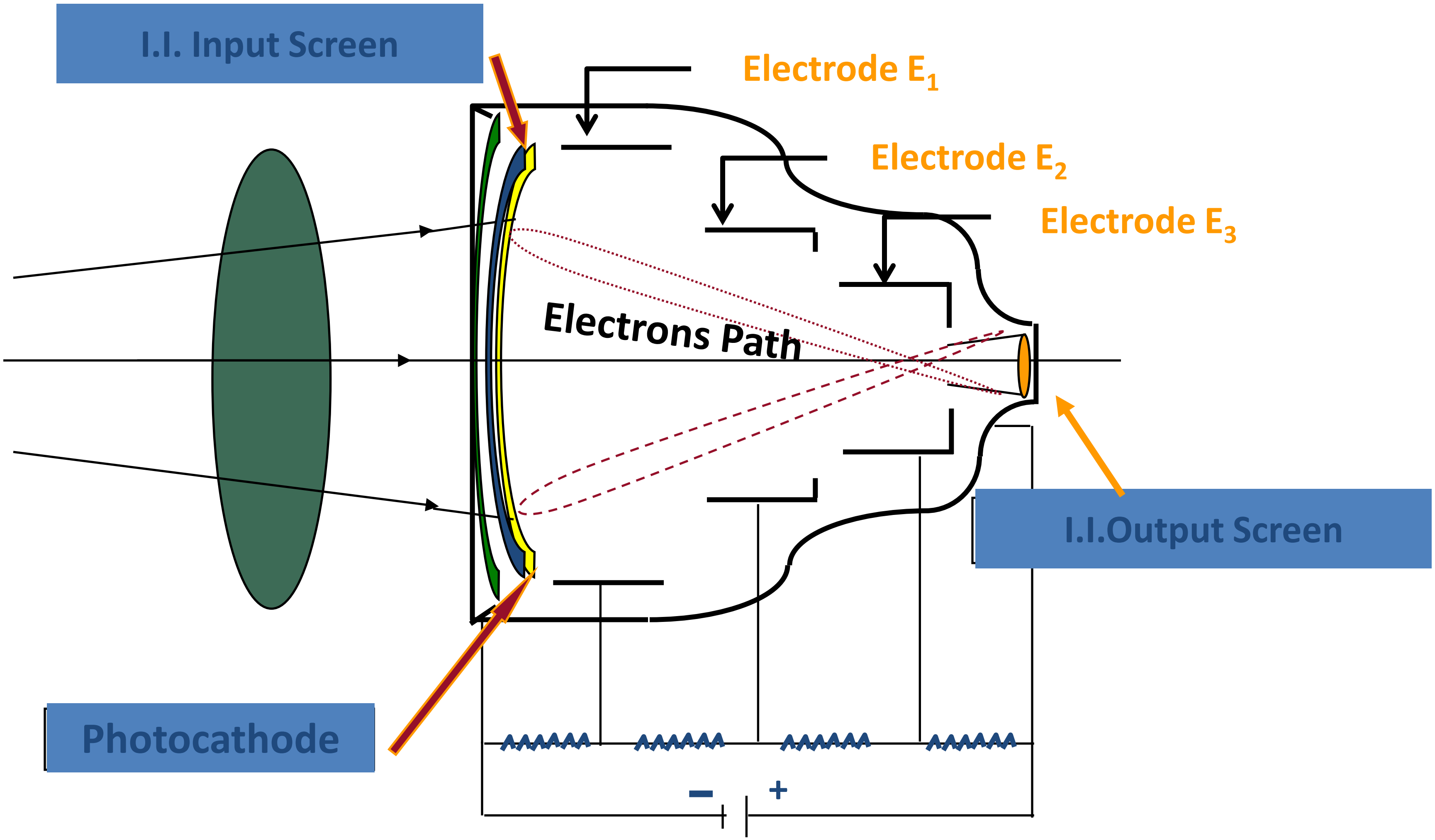


- Thin coating material on the inner side of the input screen
- It emit electrons when irradiated by light
- Number of electrons emitted α with intensity of light α with intensity of X-ray
- Commonly : antimony caesium
- It is maintained with high –ve voltage with respect to anode e.g 25kv

4- electron focusing electrodes:

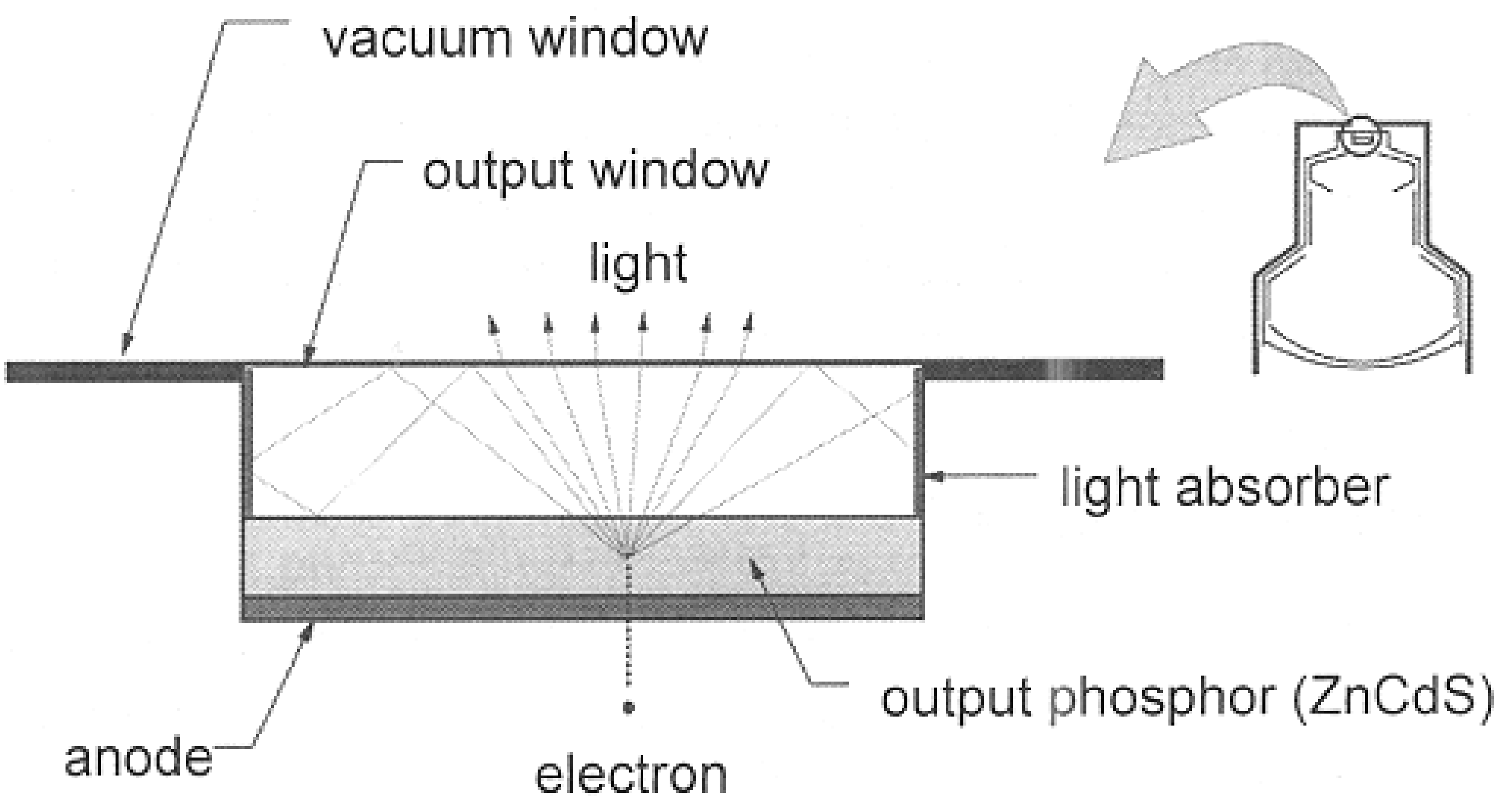
- Metal rings within the tube
- Has + ve voltage with respect to photocathode
- Constrain electrons to travel directly to output screen so that: pattern of electron intensities falling on the screen are identical as (but minified) pattern of intensities produced in the input screen
- i.e. functions as electron lens
- If absent : electrons reach the output screen in disorganized pattern → no image formed




I.I. Input Screen
Electrode E_1
Electrode E_2
Electrode E_3
Electrons Path
I.I.Output Screen
Photocathode
−
+

5- output screen:

- 25-35 mm in diameter (10 times smaller than input screen)



- Consists of:

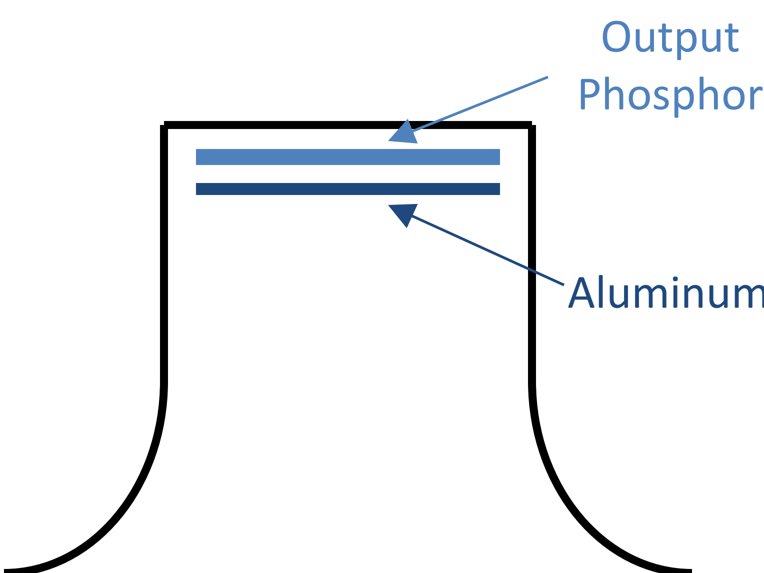
A) Thin phosphor layer (zinc cadmium sulphide ZnCdS):

  - Converts pattern of electron intensities into light
  - It must be so thin (few µms) to decrease light spread in the screen
  - It Emits green light
  - Brightness displayed in the output screen is α intensity of X-ray (X-ray doubled → screen Brightness doubled) i.e. γ=1

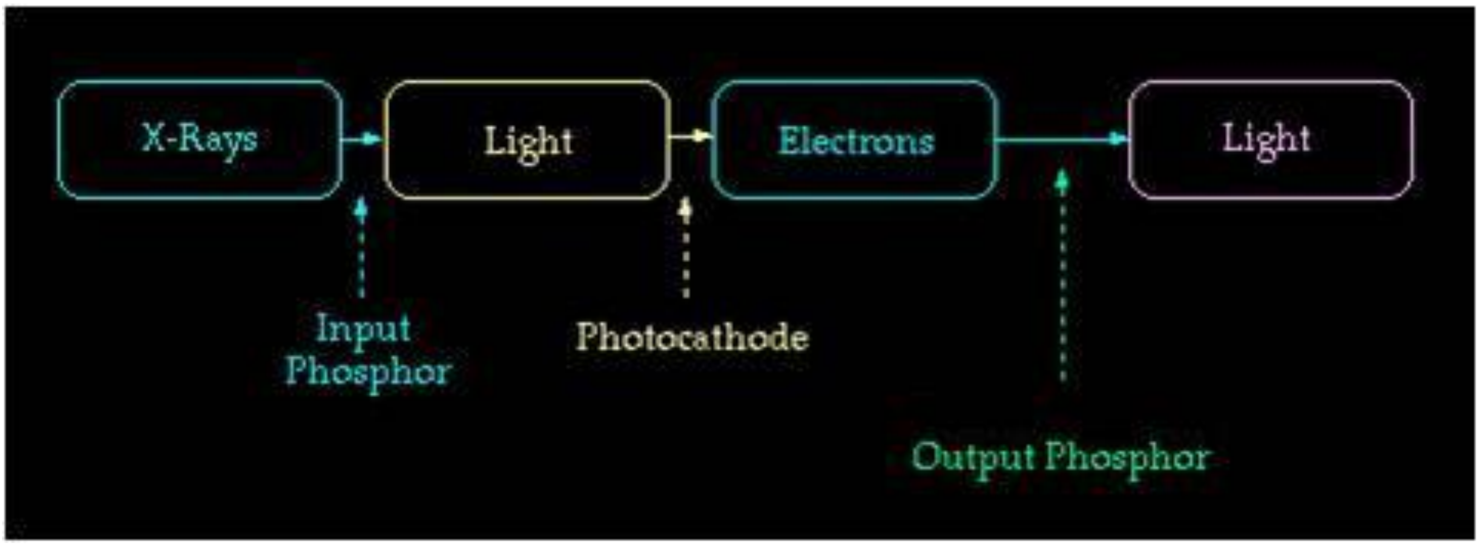
B) Extremely thin layer of aluminum (0.5) covering the output screen

  - Function:

  1) Prevent light emitted backwards towards the tube from reaching photocathode causing cascade of electron emission that would completely whiteout the image
  2) Acts as anode with +ve voltage with respect to cathode e.g 25kv → acceleration of electrons towards the output screen



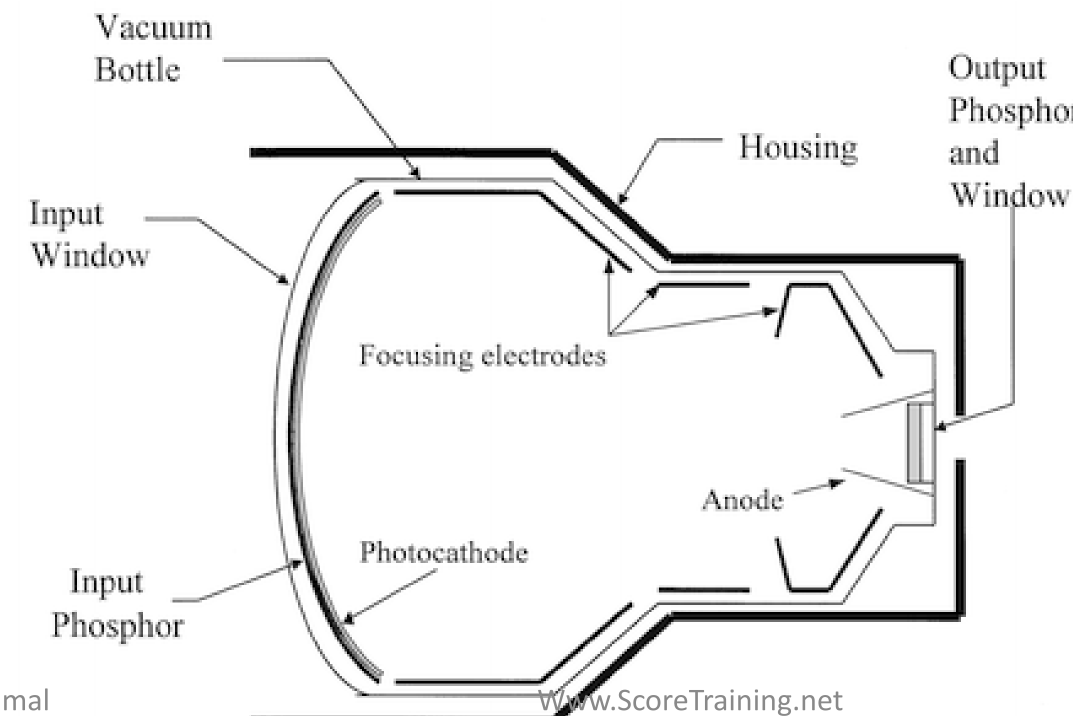
Summary of image intensifier



Fluoroscopy image characteristics

Brightness Gain:

- Definition: Ratio of brightness of the output phosphor to that of the input phosphor = degree of intensification



- Brightness gain is Caused by two factors:

1) *Flux gain :*

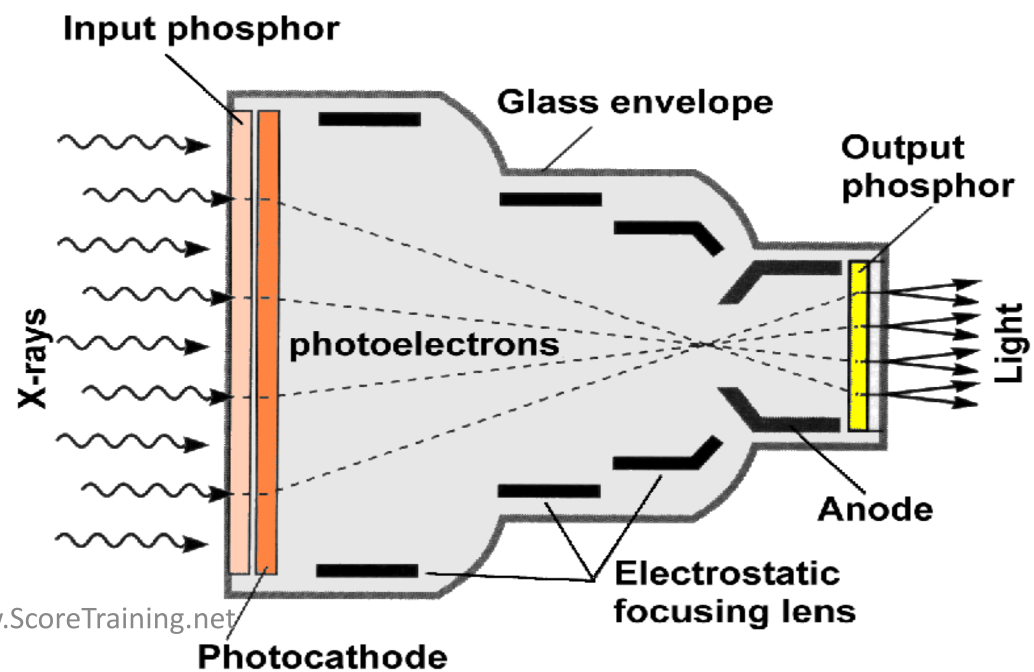
Single light photon from the input phosphor → single electron from the photocathode → accelerated at 25Kev → many (about 50) light photons from output phosphor

2) *Minification gain:*

Intensification caused by decrease of the image size from input to output screen

Equal to ratio of the **area** of both screens = $300^2/30^2$ = 100

Overall brightness gain = Flux gain x Minification gain = 50 x 100 = about 5000



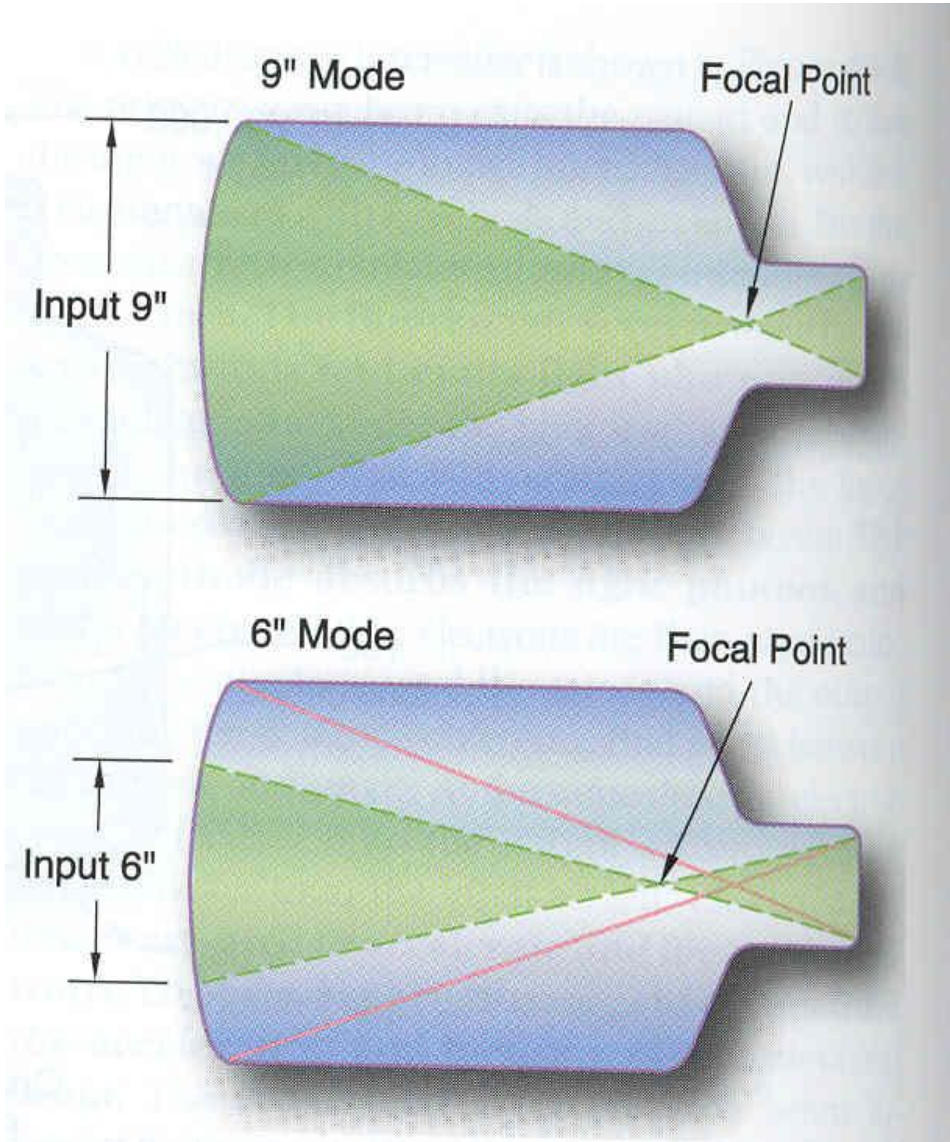
Conversion factor = Gx:

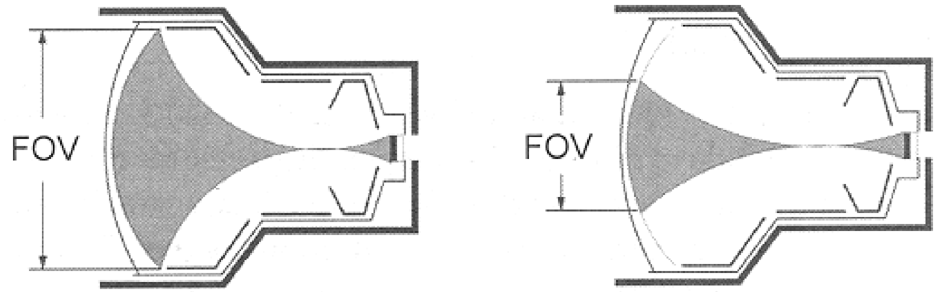
$$= \frac{\text{brightness (luminance) at output phosphor (candela.m}^{-2}\text{)}}{\text{dose rate at the input surface of image intensifier (}\mu\text{Gy .s}^{-1}\text{)}}$$

- Used to describe the performance of image intensifier (as the gain is not measurable)
- Typical value = 25-30 candela.m^{-2} (μGy .s^{-1})$^{-1}$
- Gain and Gx decrease with equipment usage due to loss of detection efficiency of phosphors

• *Magnification:*

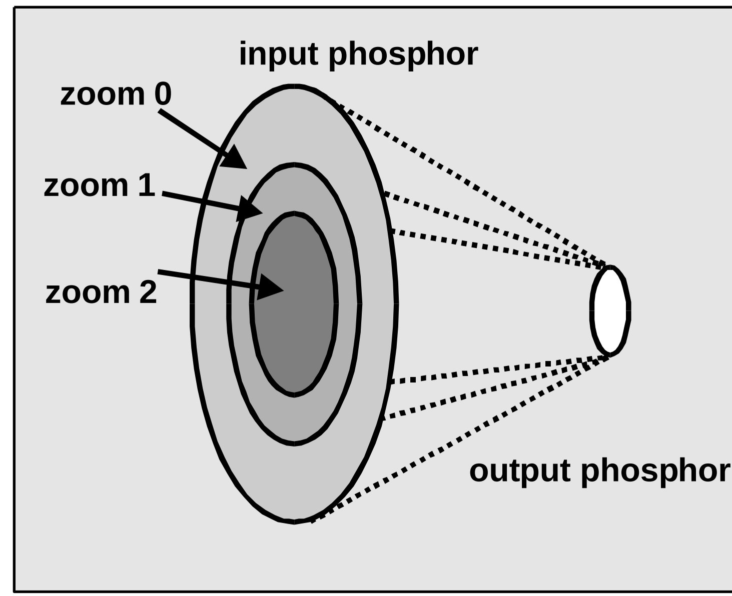
- Image in the output phosphor is a minified version of the image
- To magnify the image:
  - Voltage of the intermediate electrodes is changed → electron focus moves backwards → central part of the image only fill the output phosphor
- Advantages: better resolution





Normal Operation Magnification Mode

- Disadvantages: ↓minification gain→↓image brightness
- To restore brightness →↑exposure factors with : ↑ enterence skin dose
- All the image intensifiers offer at least one magnified fields of view



Closed Circuit TV Systems

- Used to display the image of the output phosphor
- Consists of :
  - TV Camera
  - Camera control unit
  - Monitor
- Image intensifiers and television camera tubes are manufactured so that the output phosphor of the image-intensifier tube is the same diameter as the window of the television camera tube, usually 2.5 or 5 cm

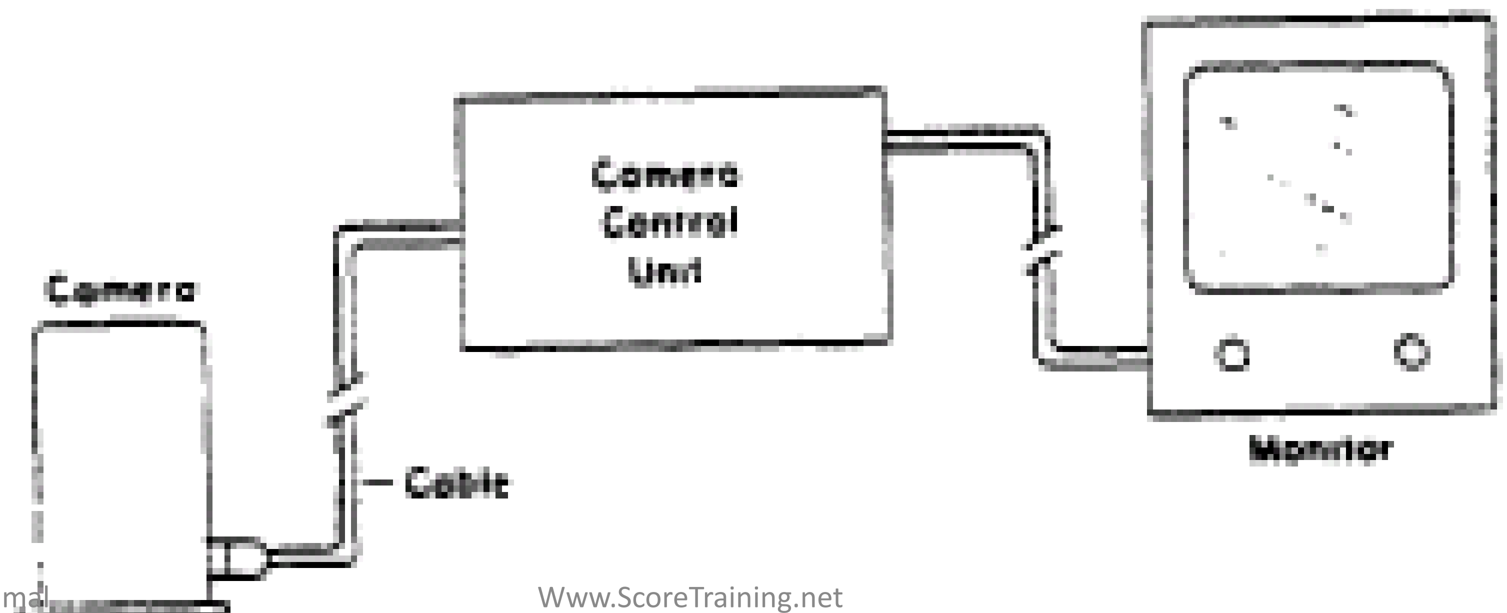
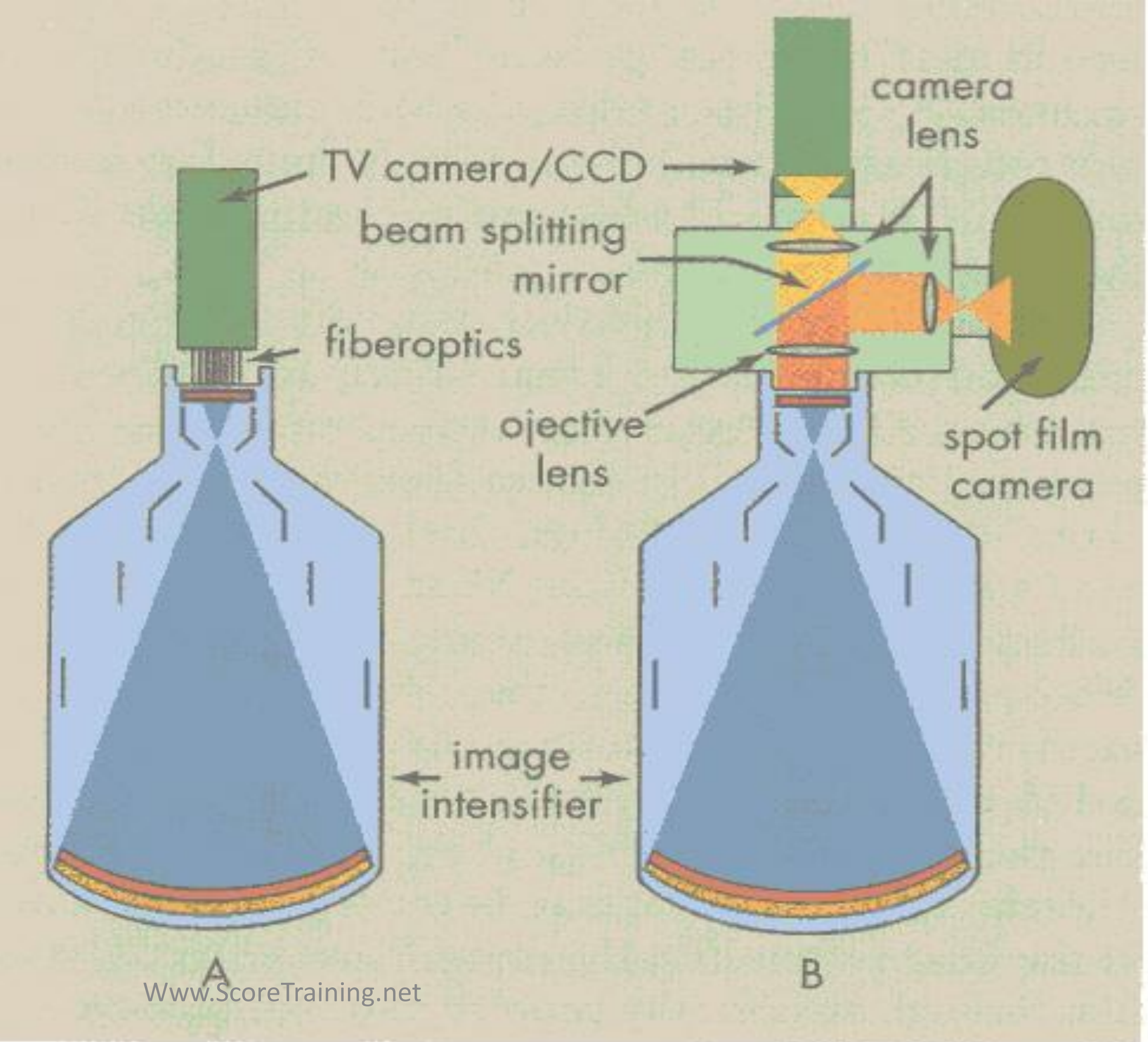


Image Intensifier – TV camera Coupling

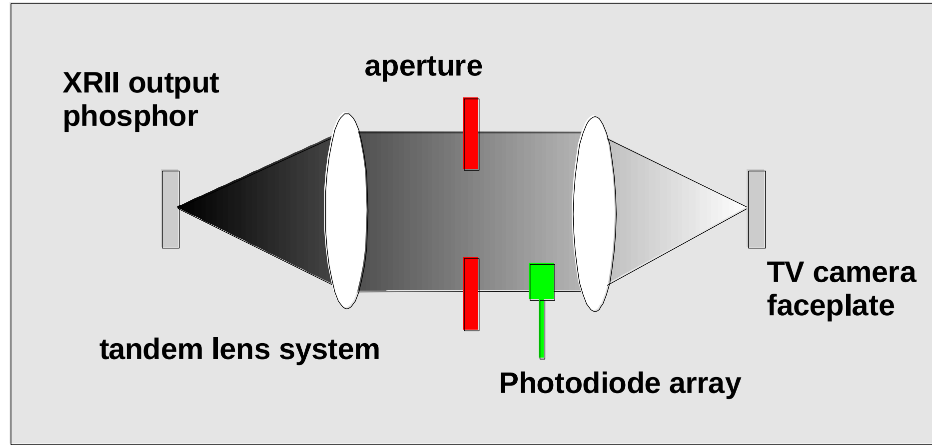
- 1) Lens coupling
- 2) Fiber Optic coupling

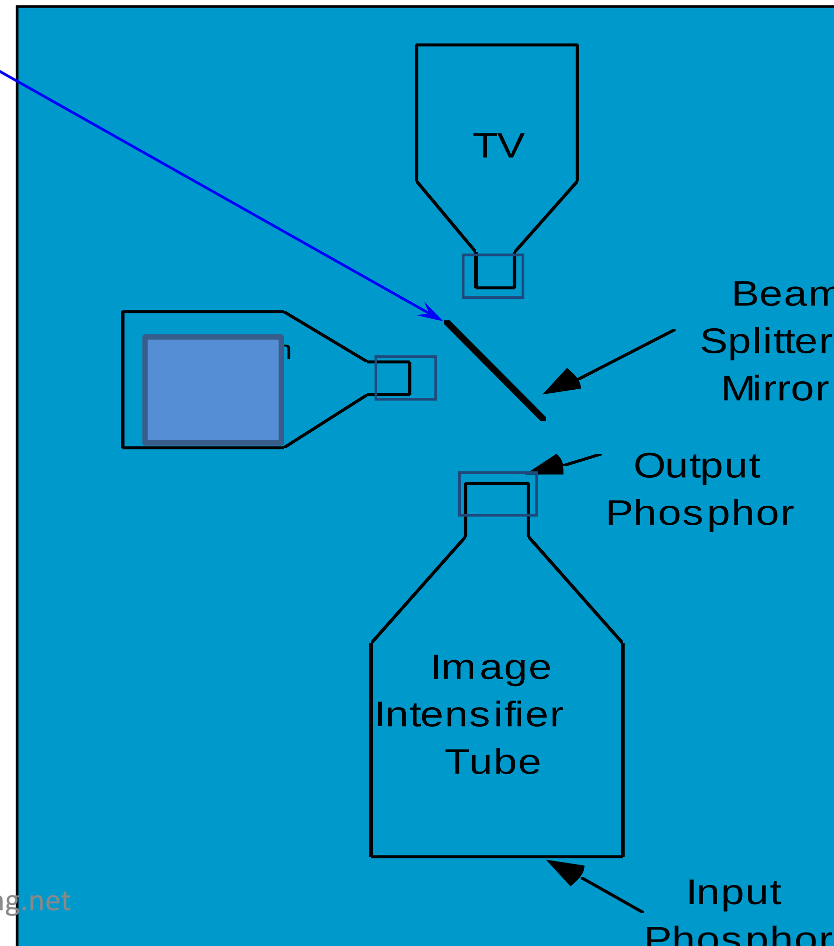


Lens Coupling

- Allows splitting of light from intensifier using semitransparent mirror (**beam splitter**)
- 90% of light to goes to the film and 10% of light to the TV camera

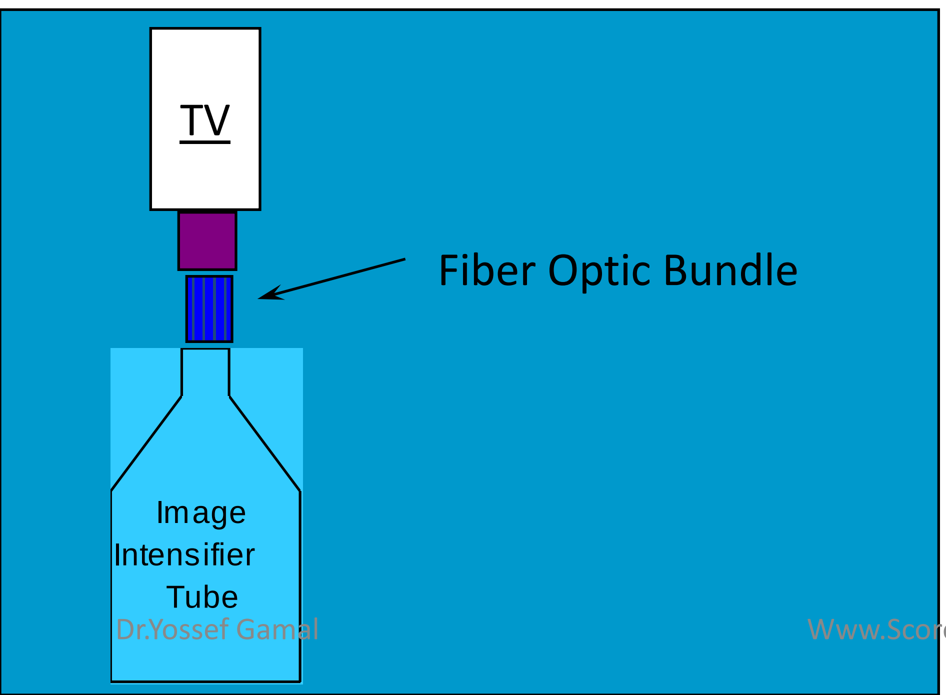
- aperture used to control amount of light falling on camera faceplate (and to control the degree of vignetting)

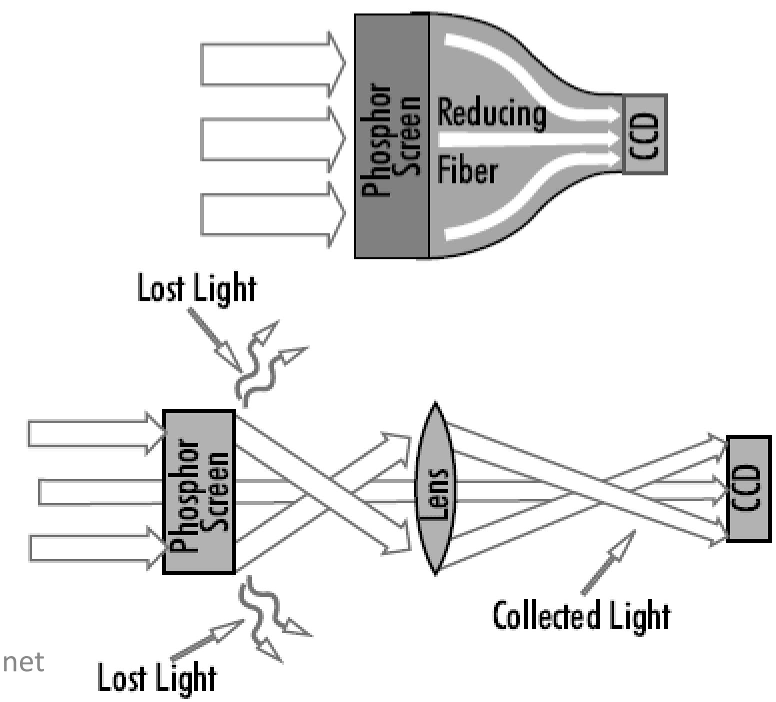




Fiber Optic Coupling

- Advantages:
  - More effective in light collection
  - Less geometrical distortion
- Disadvantage:
  - cannot record image directly from image tube (All recording done from TV)



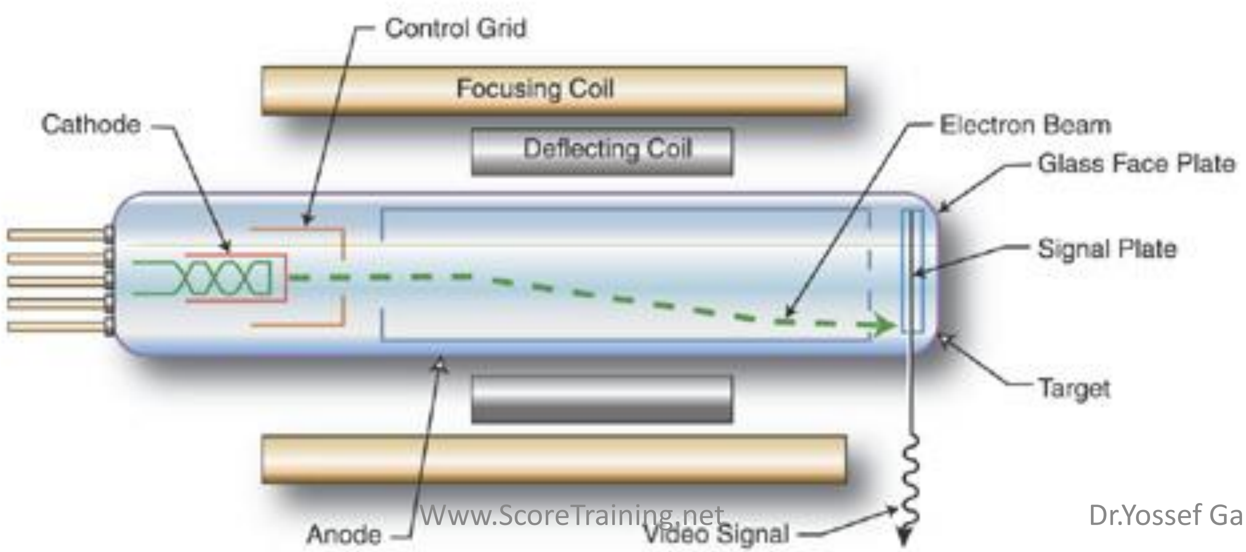


Types of TV cameras used

- **VIDICON TV** camera
  - improvement of contrast
  - improvement of signal to noise ratio
  - high image lag
- **PLUMBICON TV** camera
  - lower image lag (follow up of organ motions)
  - higher quantum noise level
  - suitable for cardiology

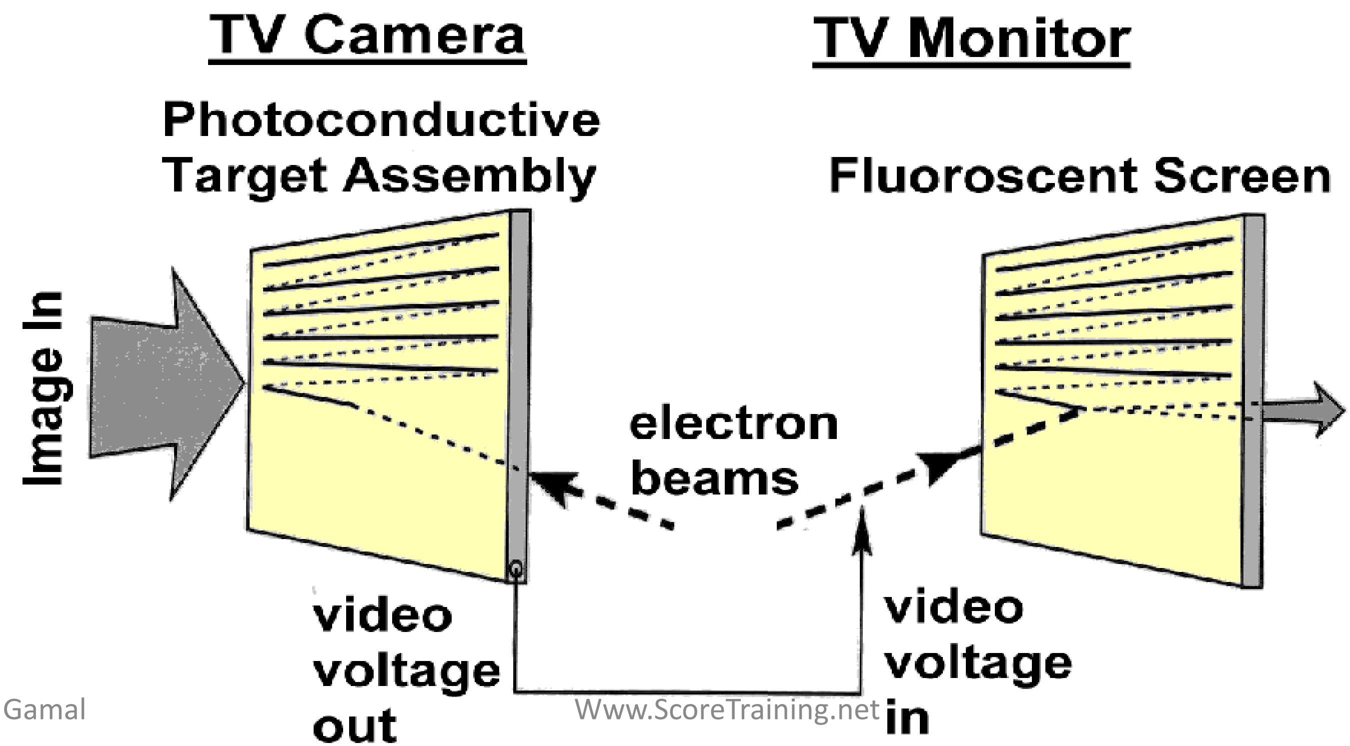
How does TV camera operate

- The camera tube is a vacuum tube , that has a photoconductor (anode) in which the light from intensifier output screen is incident.
- In a PLUMBICON tube, this layer is made of lead oxide, whereas in a VIDICON, antimony trisulphide is used
- Electron beam is produced by heating a photocathode , and is focused to the photoconductor by focusing coils so that the electron beam moves across the surface of the TV camera tube in a series of lines
- The surface of the photoconductor scanned with the electron beam results in a flowing current inside the signal plate
- The amount of current is related to the amount of light incident on the conductor.
- The current (video signal) is then transferred to the CRT monitor for display



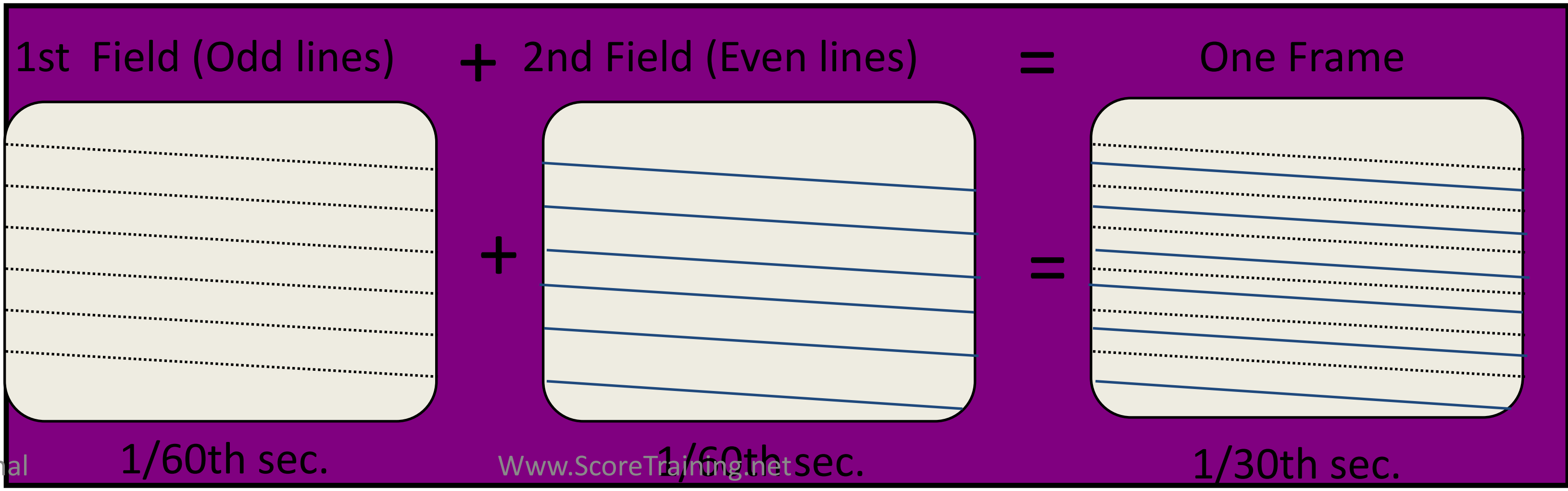
CRT Monitor

- The scanning electron beams of the TV camera and the CRT monitor move in synchronism.
- The current of the scanning beam in the TV monitor, is related to that in the TV camera.
- Consequently, the brightness of the image on the TV monitor is proportional to the amount of light falling on the corresponding position on the TV camera.

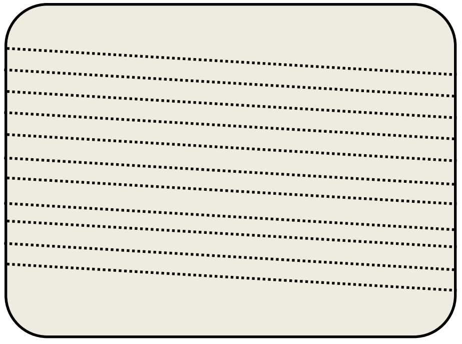


Some points regarding the CRT monitor

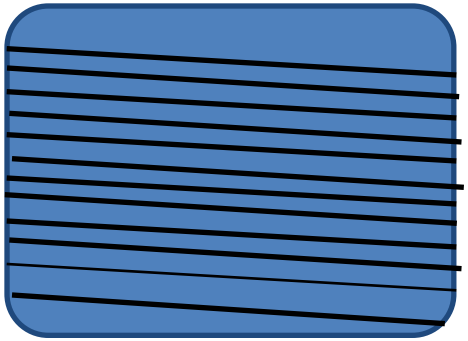
- 1) TV Interlacing: **frame** scanned in two passes, first the odd lines then the even
  - Advantage: avoids flicker
  - each pass takes 1/60th second → One frame takes 1/30th second



- 2) progressive scanning
  - used on newer systems, lines scanned in order
  - no interlacing



- CRT Vertical Resolution: proportional to # of scan lines
- CRT Horizontal Resolution: Depends on modulated signal frequency = cycles/scan line



Digital fluoroscopy

- Advantages

1- computer image storage

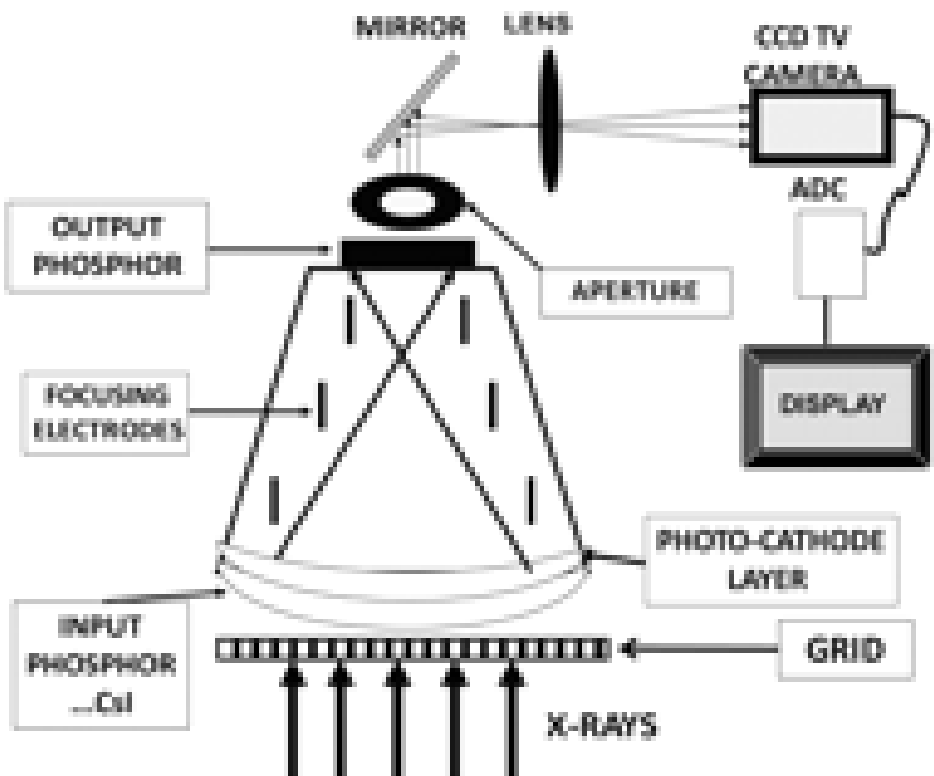
2-image processing (e.g edge enhancement , geometrical inversion , mapping to look-up tables to ↑contrast)

This processing can be done in real time

Digital fluoroscopy

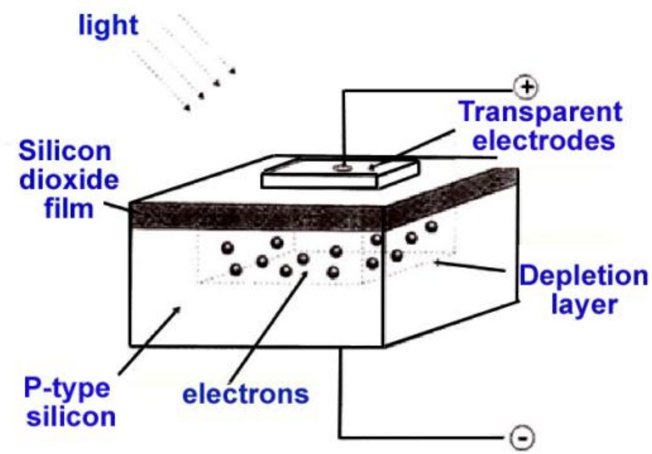
1) with use of ordinary video camera:

- Signal from video camera → ADC → digital format → displayed on the computer



2) With use of CCD camera

- Linked to the intensifier output phosphor by fiber-optic coupling
- CCD camera is formed of Input screen (amorphous silicon) divided into pixels (1024 x 1024)
- Each pixel acts as a small capacitor
- Charge collected α intensity of light falling on the pixel
- Read-out of pixel charges is so rapid (allow image sequence of 30 frames/s or faster)
- Advantages :
  - produce signal in digital format
  - High dynamic range (12-bit image depth)



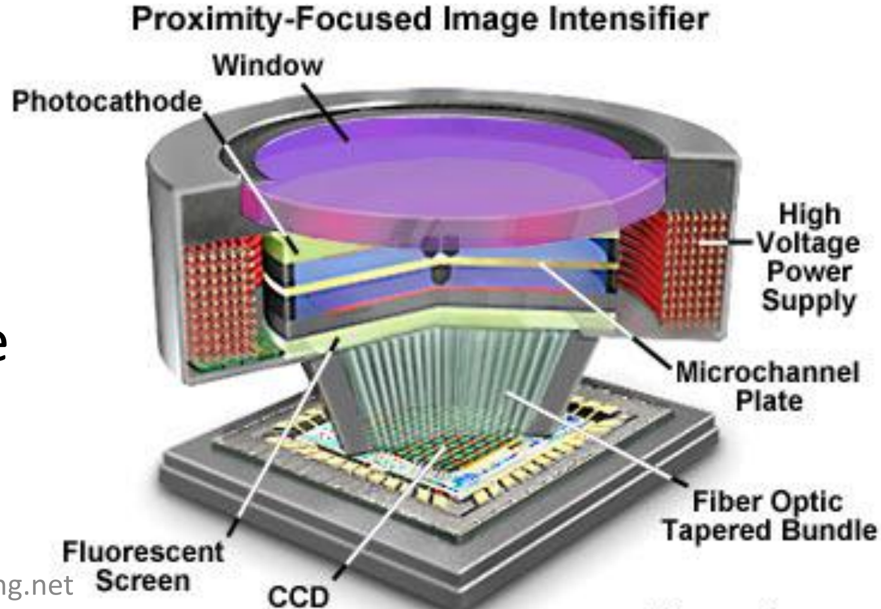


Figure 1

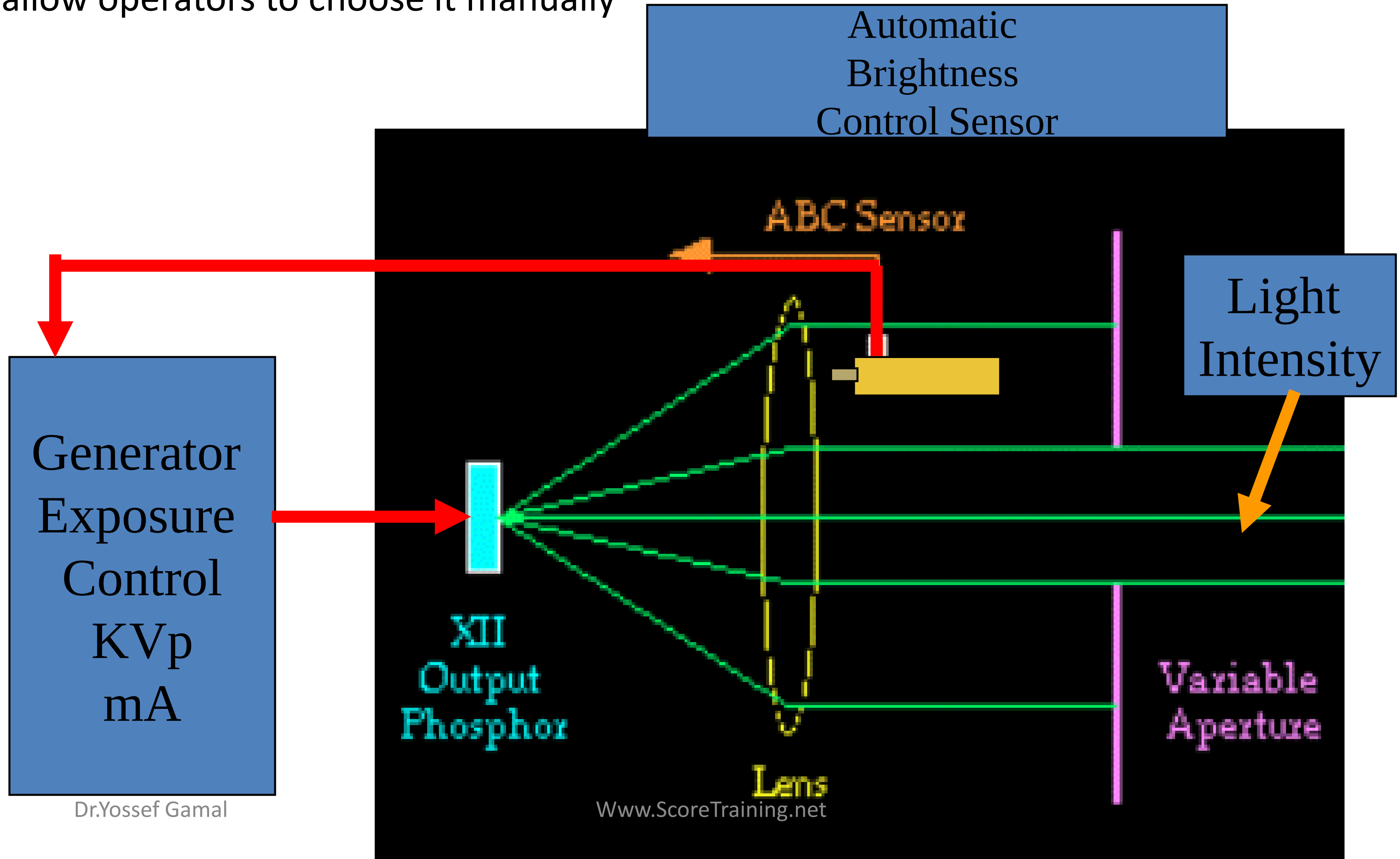
Automatic brightness control (ABC)

- In fluoroscopy manual Kv and mA control is not practical (region of the patient imaged changes rapidly)
- Aim of ABC: automatic adjustment of Kv & mA to keep the output screen light intensity to the required level

Input signal of ABC may be:

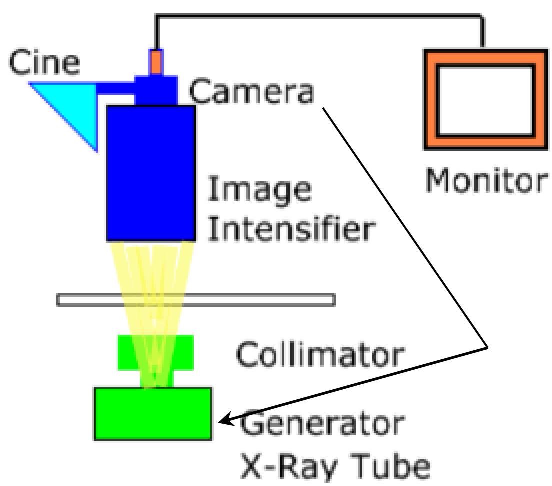
1-light intensity of the output screen of the image intensifier with optic coupling using a photodiode (older systems)

Area of output screen used is the central area (area of clinical interest), some systems allow operators to choose it manually



2- signal from camera (more in modern systems):

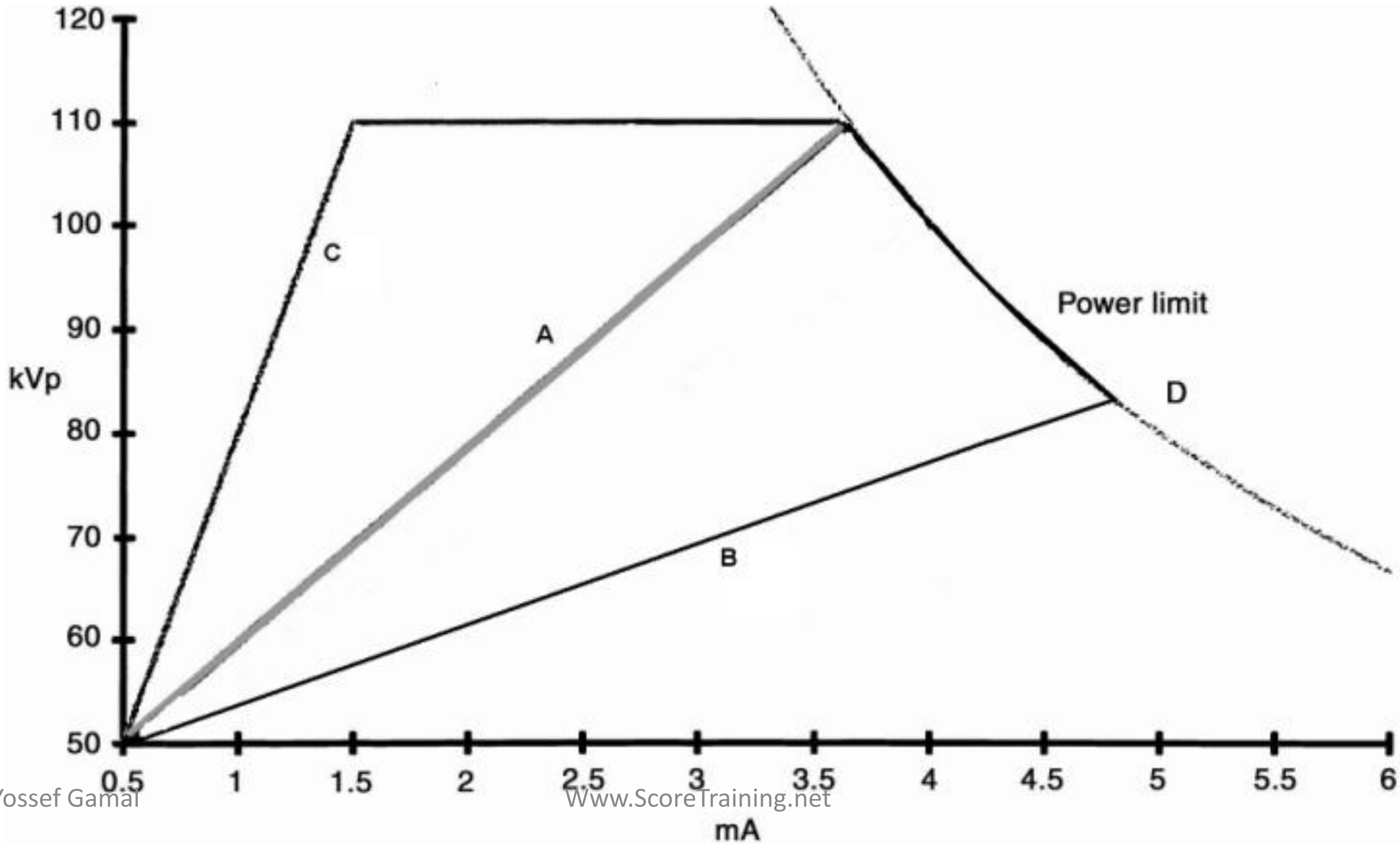
Signal change feedback to the generator →automatic adjustment of Kv & mA



Anti-isowatt curves:

- ABC is controlled by different types of programmed curves

Curve A: increase in radiological thickness→↑Kv & ↑mA (maximum power limit = 400 W = 400 J/s)



Curve B = image quality weighted curve:

Tube potential is kept between 60-70 Kv , which is optimum for Iodine imaging (k-edge = 33 kev)

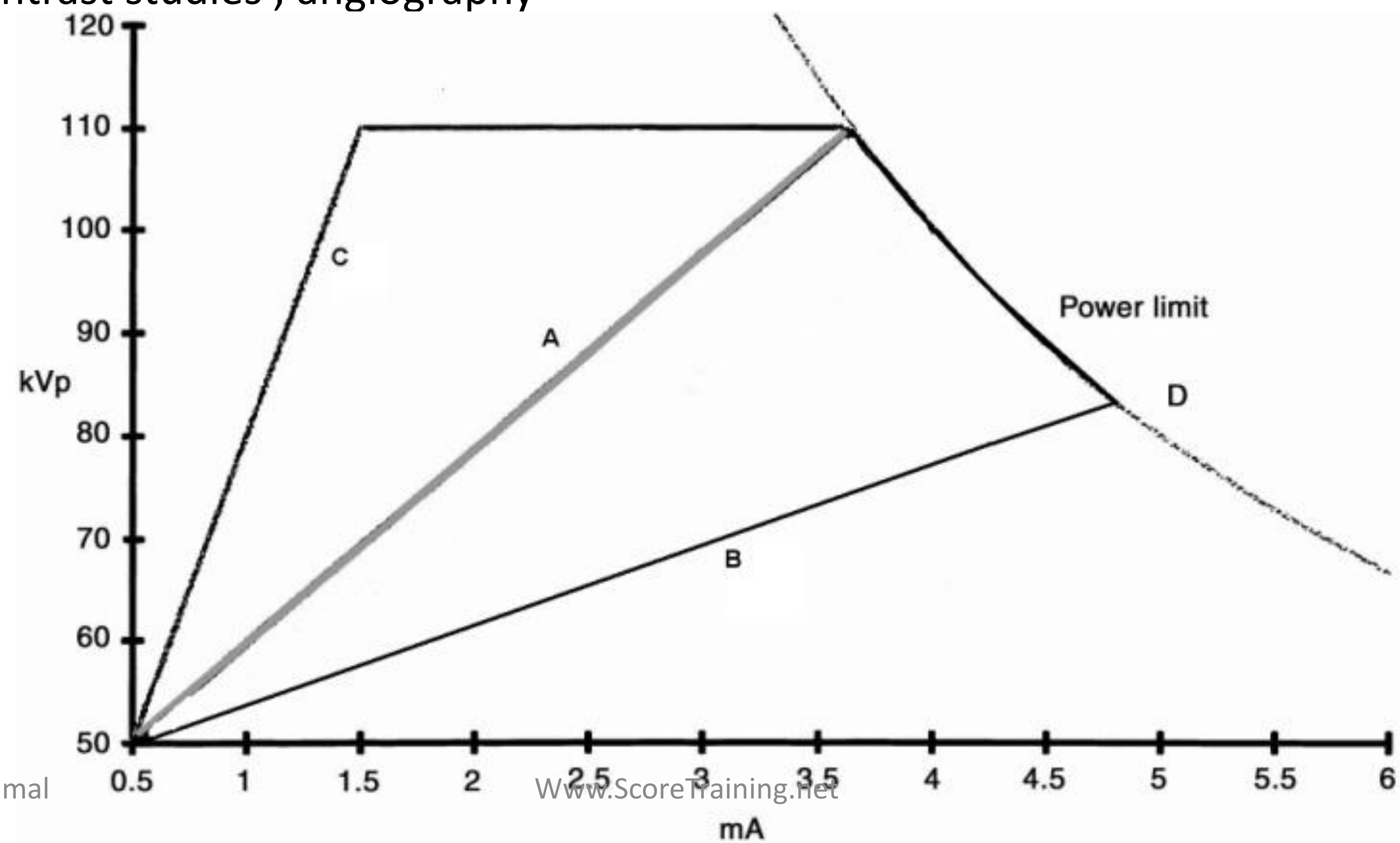
So that when the radiological thickness increase →↑mA

At power of 400 W (power rating) tube cant sustain → if more thickness → ↑Kv & ↓ mA (so that power rating is not exceeded

Advantages : good image contrast

Disadvantages : ↓kv →↑dose

Uses: contrast studies , angiography



Curve C: dose weighted curve:

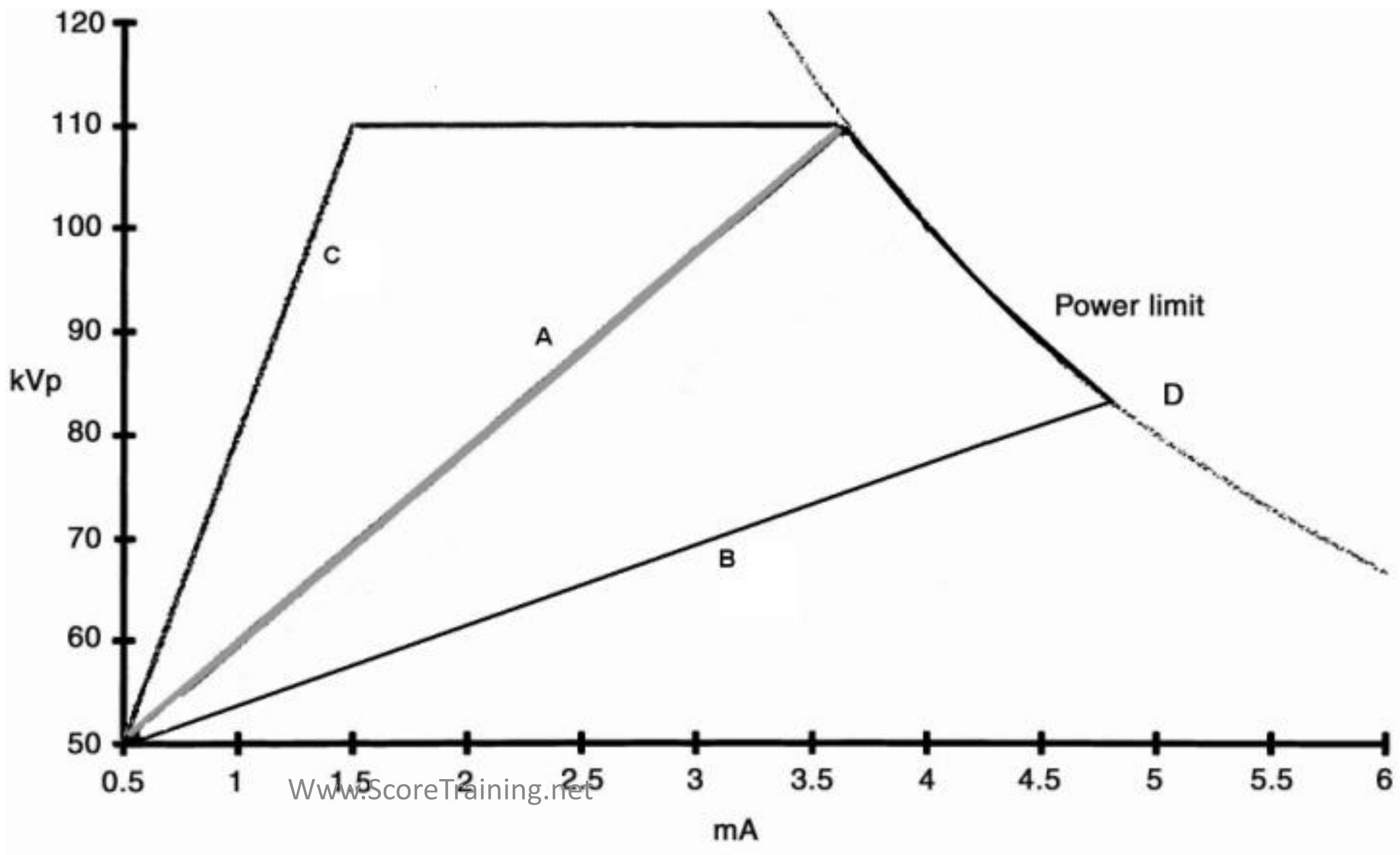
Increase of radiological thickness →↑Kv rapidly up to maximum Kv that can be sustained by the tube (kv rating)

If more thickness → maximum Kv is used with increasing mA (= high kv curve)

Advantages: ↑Kv → low patient dose

Disadvantage: less image quality

Uses: pediatrics



Automatic gain control

- Alternative to ABC , but adjust brightness by adjusting the gain of TV system
- Disadvantage : either will↑ image noise or will cause unnecessary dose
- Example:
  - fluoroscopy is used at certain Kv and mA
  - When thickness decrease →kv and mA are stable and AGC is in charge → image brightness is adjusted but the kv and mA are high for the thickness imaged →

    1-unnecessary dose

    2-less noisy image

Think what will happen if the thickness increase?

Fluoroscopy dose rates

Fluoroscopy dose rate depends on:

1- DQE of image intensifier (detection efficiency is high for CsI = 60%)

2- level of noise that can be accepted:

- Input dose rate of image intensifier is usually adjusted to the range of 0.1-0.5 µGy/s (about 0.25)
- The lower the input dose , the greater is the noise
- ABC will give lowest brightness possible at which compensation by TV gain will cause accepted noise

3- Magnification (field size) :

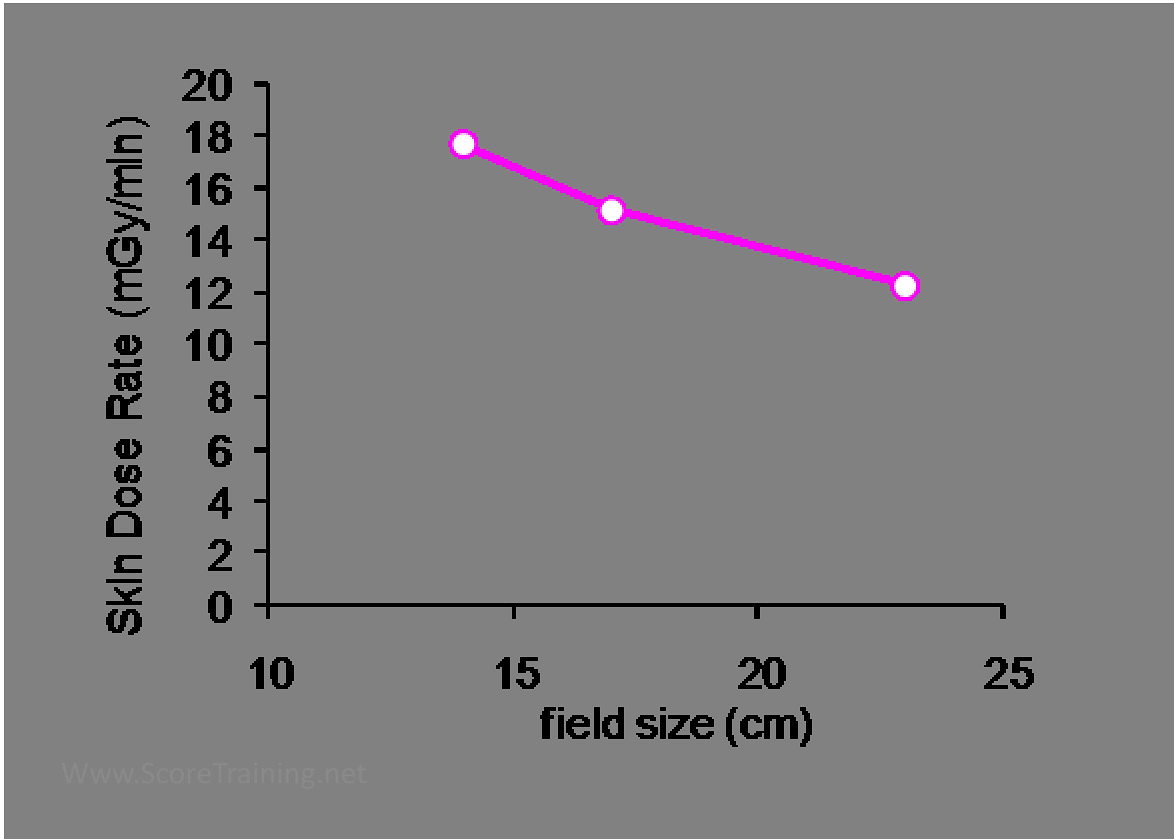
magnification →↓ of the minification gain →dose is ↑ to keep the same brightness → ↑ ESD

But the area scanned is also decreased→ dose area product is unchanged (theoretically)

Yet in practice:

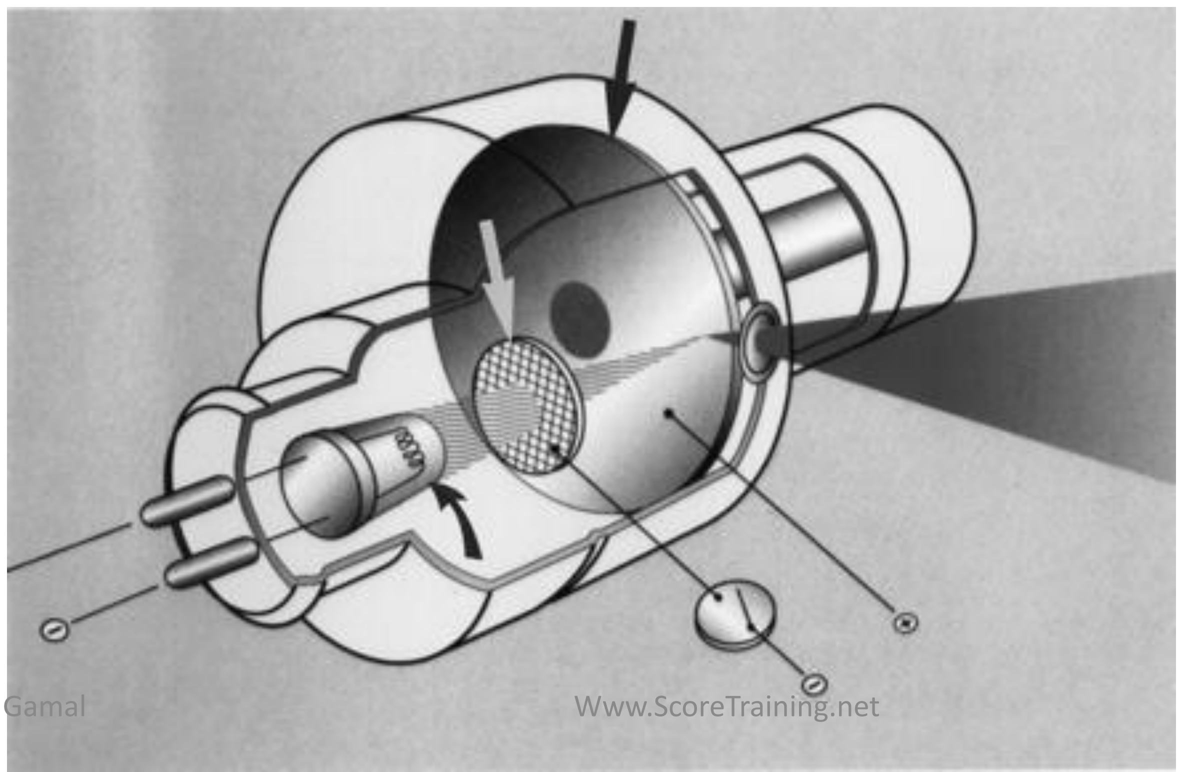
compensation is not only done by ↑ dose , but also by ↑ TV gain

So that dose area product is reduced to some extent during magnification



4- pulsed fluoroscopy: two types:

- A) primary control pulsed fluoroscopy:
  - X-ray generator switching on and off on regular intervals
- B) Grid controlled tube (direct control):
  - Circular tube electrode between filament and target with –ve voltage (2kv) is switched on and off → electrons pass and then repel and then pass … etc.
  - Advantages: more precise switching with good control of X-ray

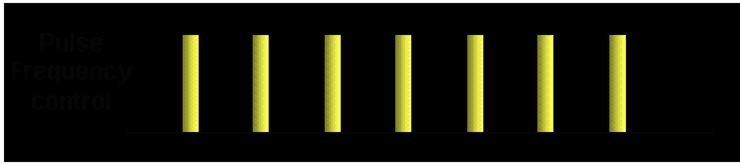


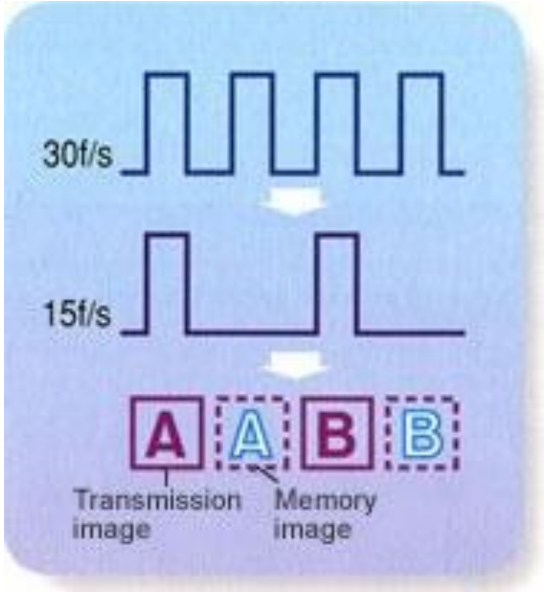
- At rate of 25-30 pulses/s → the eye is not able to detect pulses
- Most of continuous fluoroscopy are actually pulsed
- Each image is retained on the monitor until the following is displayed
- at low pulse rate:

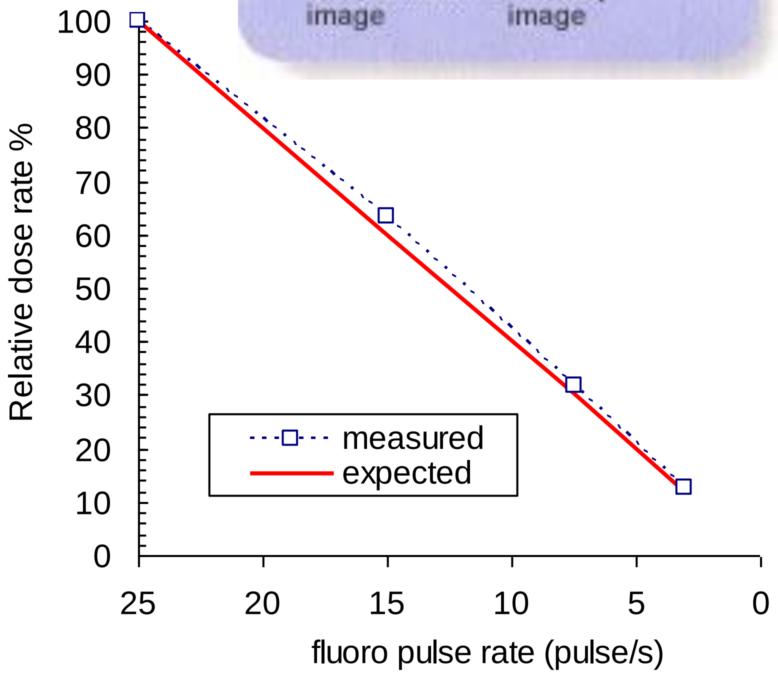
1- no flickering

2- image lag

3- dose rate falls (but not exactly in proportion to the decrease in pulse rate – equipment design dependant)





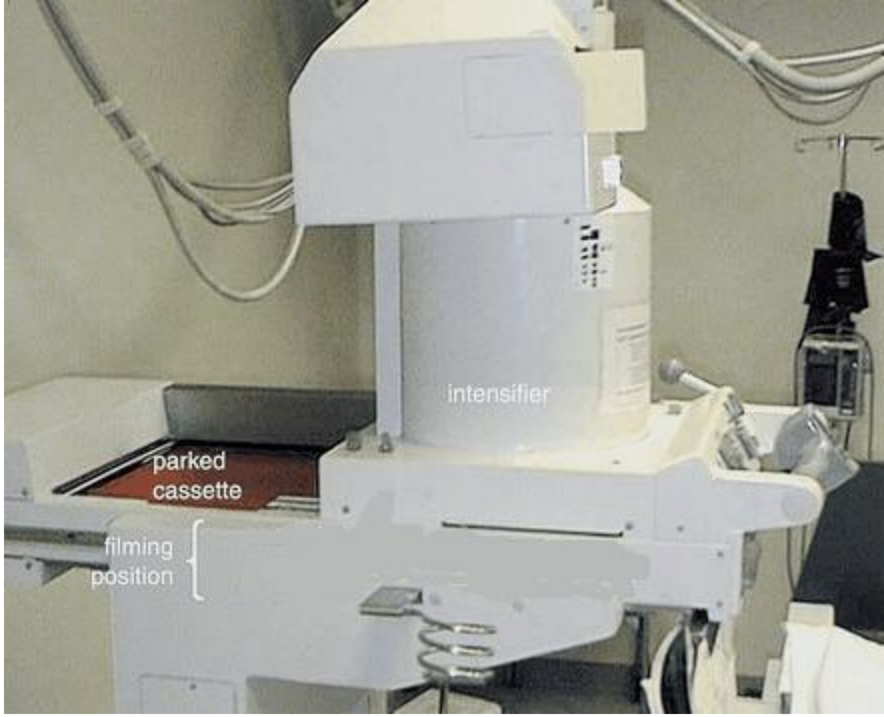


Fluoroscopy and ESD

- Entrance surface dose (ESD): can never exceed 100 mGy/min (or 50 mGy/min) for any field of view in fluoroscopy
- In practice with modern equipment : it is in the range of 10-30 mGy/min

Fluoroscopy recorded images

- Fluoroscopy is usually used for positioning (e.g. biopsy) , it is rarely diagnostic (real-time , and poor image quality)
- For diagnosis, images must be recorded and stored by some way in high quality during fluoroscopy operation



1- non digital fluoroscopy

<u>A) spot films with film screen:</u>

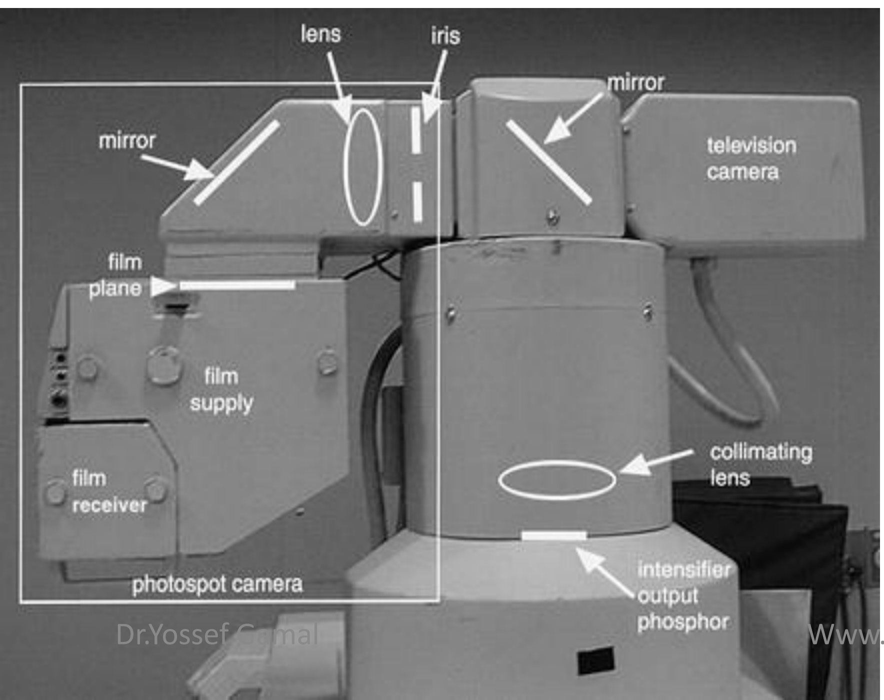
- Cassette holder (with film screen inside) is parked outside the radiation beam
- On pressing the switch to record the image → cassette is driven between the grid and the image intensifier and exposure is made (with delay of about 1 s.)
- Multiple successive exposures can be made in single film using collimator (e.g. barium swallow)

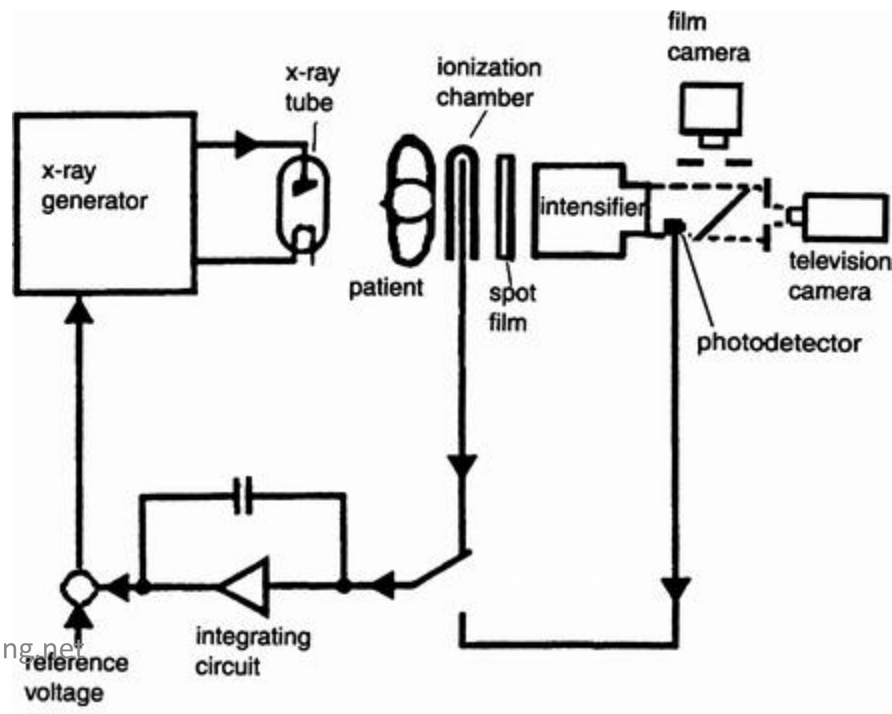
B) spot films with fluorography

- Definition: recording images produced by image intensifier output screen
- Mirror is introduced between output screen of the image intensifier and the TV camera to take spot films using static camera
- Film size = 105 mm [30% of films produced in method (A)]
- X-ray tube operated in radiographic mode (about 300 mA)

  i.e. High mA (with short exposure time) →decrease noise

N.B: Cine camera may be used instead of static camera (e.g. cardiac studies)
Using pulsed X-ray exposure (pulse rate = camera frame rate)





2- spot images in digital fluoroscopy

- Always done using fluorography

A- Last image hold = fluorograb:

- Computer stores the last frame of fluoroscopy (continue to appear in the monitor after switching off the X-ray)
- Advantages: operator can inspect the image without additional radiation
- Disadvantages: low quality image

B- digital spot images:

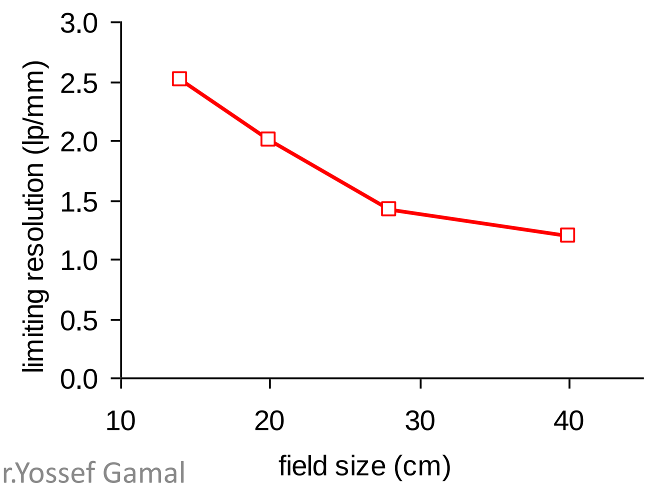
- Single shot image taken with ↑mA to decrease the noise
- Required image intensifier dose to provide adequate image quality = 0.5 – 5 µGy (exact value depends on magnification degree and clinical requirement)
- If 0.5 µGy is required to produce the spot image → equal to dose produced by 2 seconds of fluoroscopy screening (remember Image intensifier dose rate)
- N.B: Sequential images can be recorded (total number is dependant on computer memory e.g. angiography

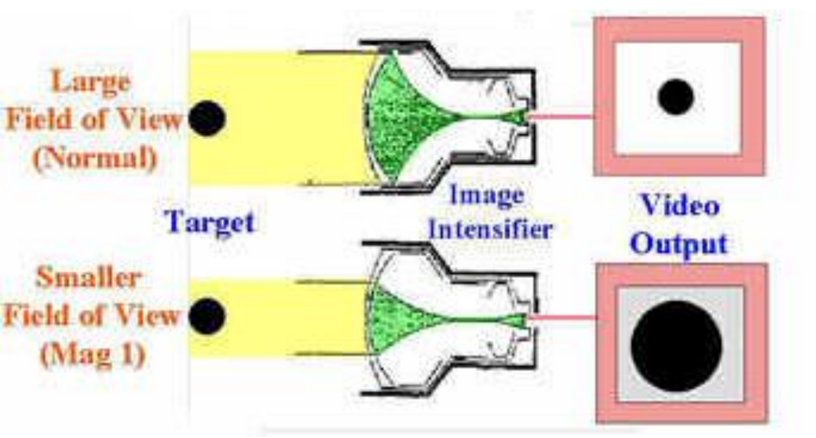
Spatial resolution of fluoroscopy:

1- in image intensifier itself:

- Resolution is limited by spread of light in the output phosphor
- At this step : resolution = 4-5 lp/mm (somewhat better for magnified views)
- Spatial resolution α image size at the input face of image intensifier

i.e. : Resolution is defined in terms of the image size at the input face of image intensifier





2- resolution seen in the monitor display:

More limited than step 1

a) <u>Using CCD :</u>

CCD consists of 1024 x 1024 pixels

So that : for 350 mm FOV → pixel size = 290 µm → spatial resolution = 1.7 lp/mm

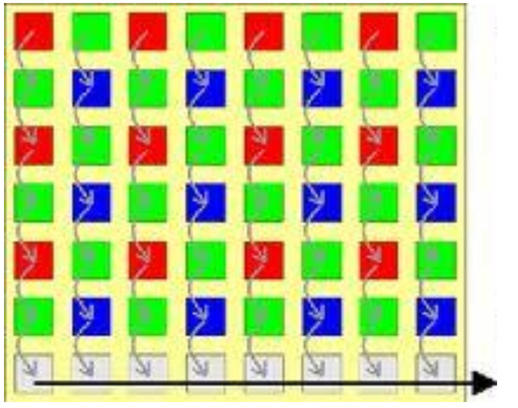
Yet , actually , it is not more than 1.2 lp/mm)

Improved to 3 lp/m for magnified view

b) <u>Using Older vacuum tube camera:</u>

Similar resolution as CCD

What are the factors affecting resolution here?



Noise in fluoroscopy

- Significant feature of fluoroscopy (why?)
- Quantum sink corresponds to the photons absorbed in the input screen

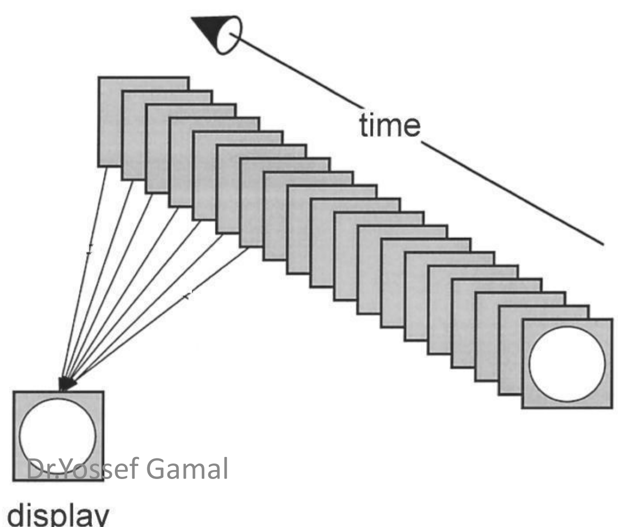
i.e. nothing will ↑S/N ratio after this step (e.g. camera gain)

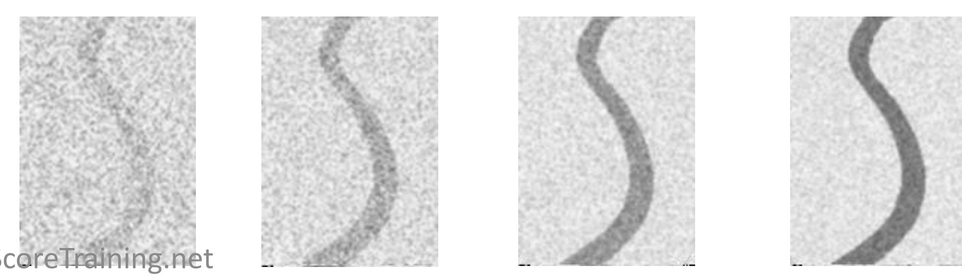
- To decrease the noise:

1) Increase input dose rate by ↑ mA
2) frame averaging: adding signals from successive frames
   - Advantages:

     a- ↓ noise (equivalent to increasing exposure time) with higher ability to see low contrast details

     B- smoothing the image
   - Disadvantages: blurring if high level of motion between frames
   - ↑number of frames added →↓image noise →↑blurring





Frame 1 | Frame 1+2 | Frame 1+2+3 | Frame 1+2+3+4

Veiling glare

- Causes: scattering effect in the image intensifier:
  1- light scattering in the output window (mainly)
  2- X-ray and light scatter in the input phosphor
  3- electron scattering in the tube itself
- The larger is the image intensifier , the greater is the Veiling glare
- Effect:

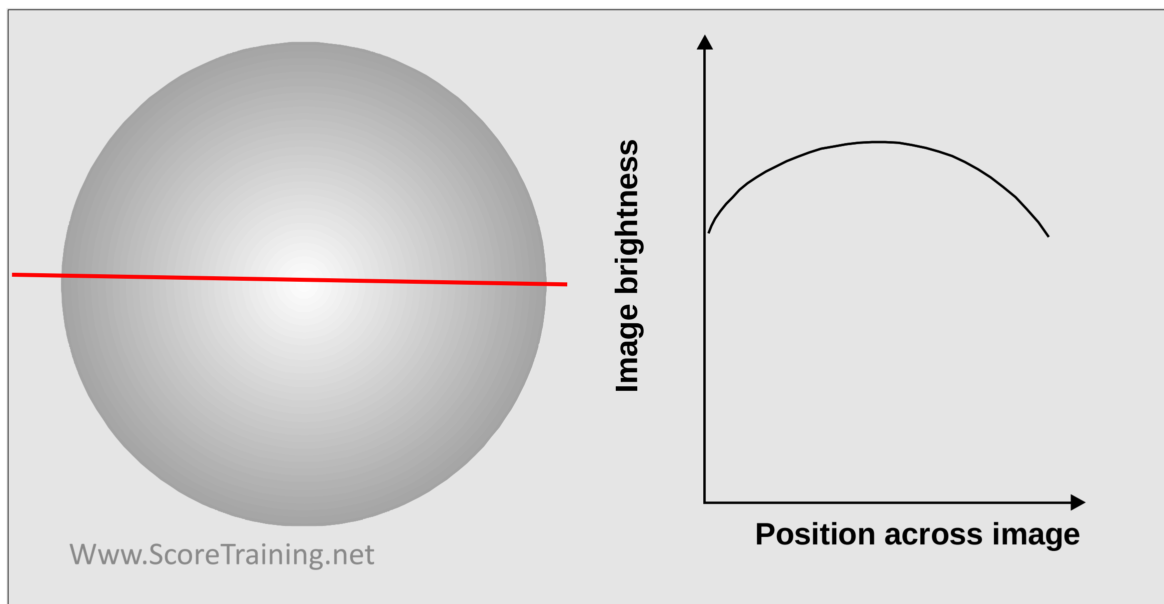
1- decrease the contrast because dark regions of the image appear lighter

2-makes the central area of the image appear brighter than the periphery = vignetting

N.B: other causes of vignetting :

A) periphery of the image is displayed over larger area of the input screen

B) poor periphery focusing



Geometrical distortion

- Types:

<u>1- pin cushion distortion:</u>

Magnification towards the edges of the image

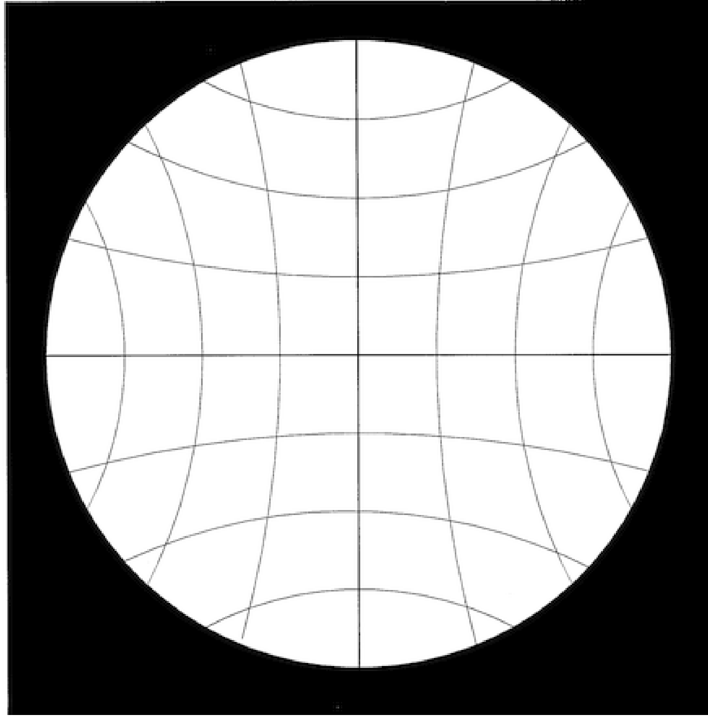
Due to curvature of the input screen

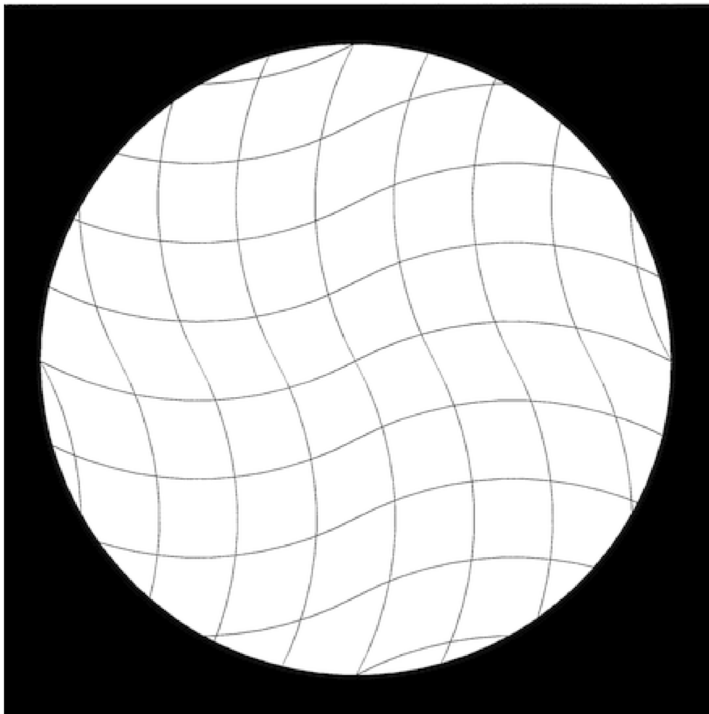
<u>2- S- type distortion:</u>

Impose curvature on the straight line features

Due to ambient magnetic fields influencing path of electrons from input to output screens

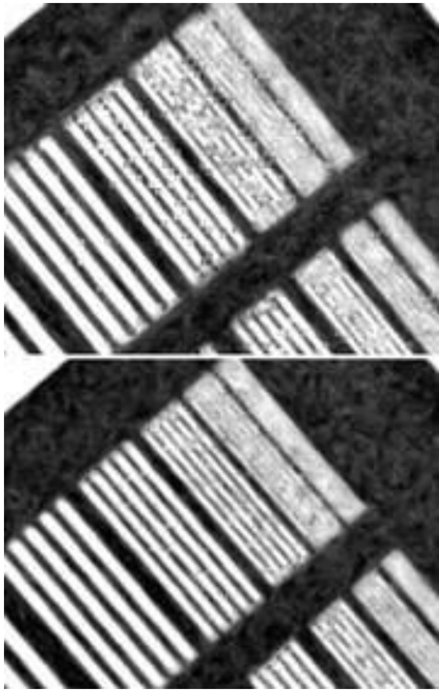
Both are insignificant when imaging complex shapes within the body





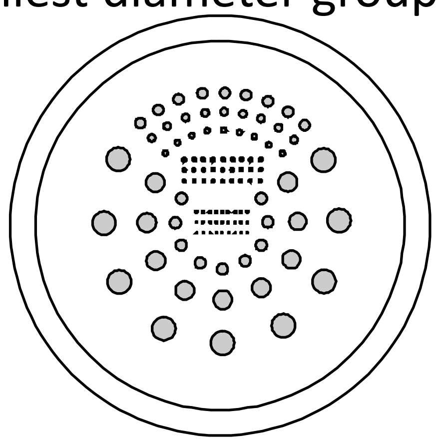
Testing the spatial resolution

- Using grid test
- Test is carried out without any attenuating materials in the beam
- ↓ kv is used to minimize the scatter
- Detect any deterioration in the image intensifier focusing

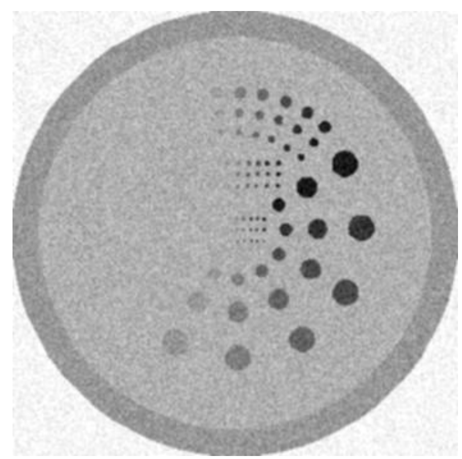


Testing the contrast resolution

- under standard fluoroscopy conditions (70 kv , 1-2 mm copper filter)
- Using low contrast test object (e.g. Leeds test object) which is a flat disc , 6mm in thickness , 200-300 mm in diameter
- Contain groups of circular inserts of ↑ Z,
- Example: 12 groups of circular details
- Each group has diameter A , and Each group is composed of 9 disks
- Thickness of the disks of each group increase progressively to produce varying levels of contrast
- Observer is required to count the number of details that can be seen in each group
- Usually it is not possible to see more than 6 details in any group , and more than 1 detail in the smallest diameter group

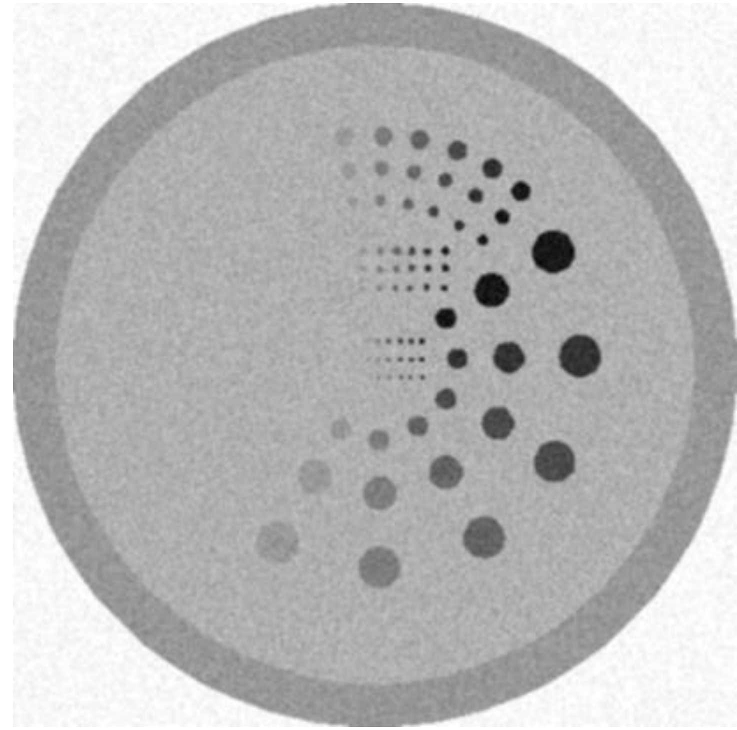


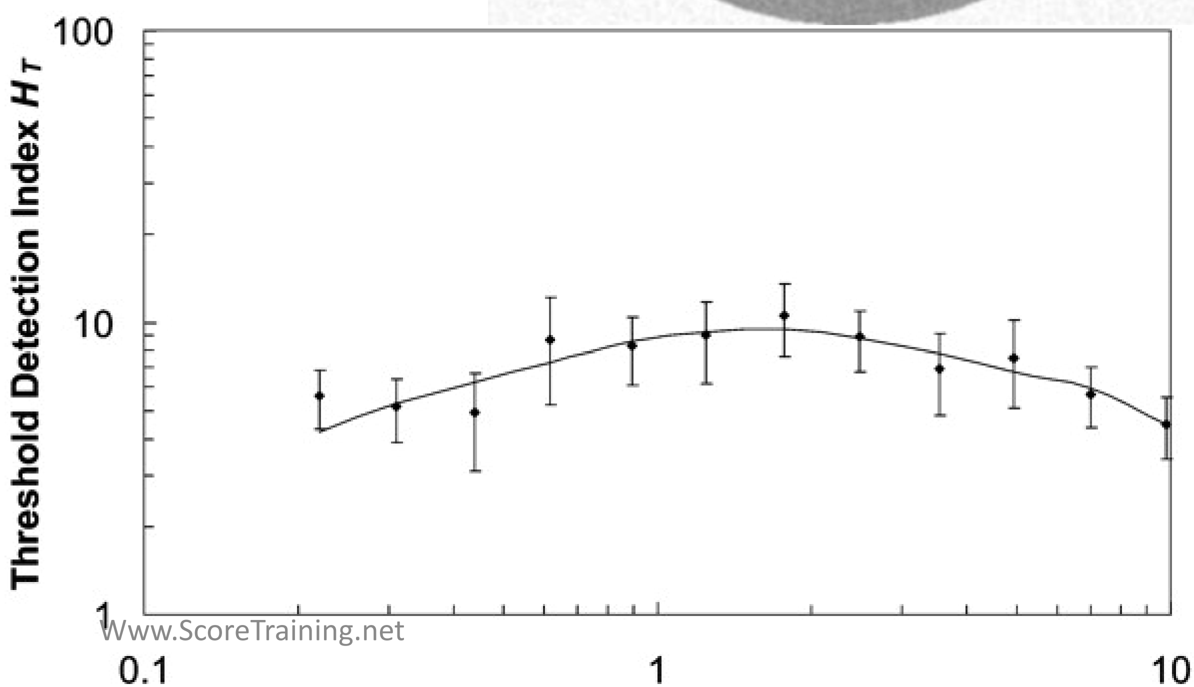
Test object made from Al, Cu or Ag discs



x-ray image

- $H_t(A) = [C_t(A) \times A^{1/2}]^{-1}$
- $H_t(A)$: threshold detection index of group A
- $C_t(A)$: threshold contrast of group A (minimum visible contrast)
- A: diameter of the group
- $H_t(A)$ is plotted against A to detect imaging performance (by comparing it to the previous tests)





3) Flat Panel Detectors

- Flat panel detectors are becoming more and more used in fluoroscopy.
- Flat panel detectors will replace the image intensifier-TV based fluoroscopy systems
- Indirect conversion (with an intermediate step) most common

The use of flat panel detectors instead of image intensifier in fluoroscopy

	Flat panel detectors	Image intensifier with CCD camera
DQE	60-65 %	60-65% (both use CsI)
Dynamic range and contrast	Very high (14 bit depth) → better contrast	CCD has good contrast resolution (12 bit depth) , yet , contrast is limited due to veiling glare → contrast ratio is not better than 30:1
Pixel size	150 µm (resolution = 3lp/mm)	400 µm (resolution = 1-1.2 lp/mm)
magnification	Does not affect spatial resolution (pixel size is the same)	Resolution improve with magnification (for the smallest field of view resolution of both systems are comparable
Geometrical distortion	-ve	+ve
CT scanner	Can be used in multislice CT scanners	Can be used but limited due to circular FOV and geometrical distortion

Types of fluoroscopy tables

1) TUBE ABOVE THE TABLE = *Over couch Tubes*

2) TUBE UNDER THE TABLE = under *couch X-ray tube*

3) C-ARM FLUOROSCOPY:
Tube and intensifier move together around the patient

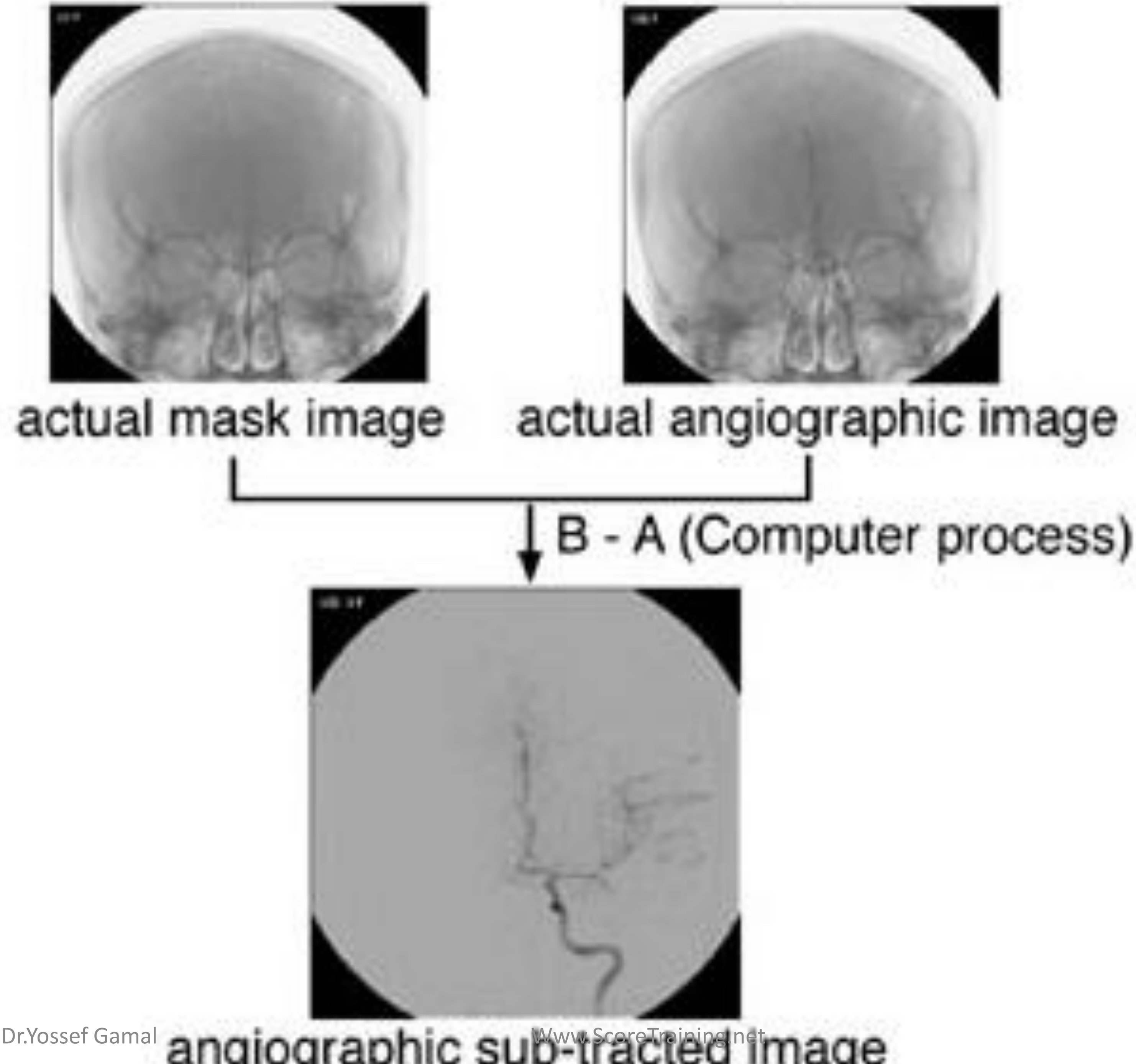
Digital subtraction angiography

- Objectives:

1) produce image of contrast filled vessels in isolation from other tissues

   This will increase vessels clarity and decrease dose of contrast

2) rapid image succession to avoid patient movement


actual mask image
actual angiographic image
B - A (Computer process)
angiographic sub-tracted image

- Process:

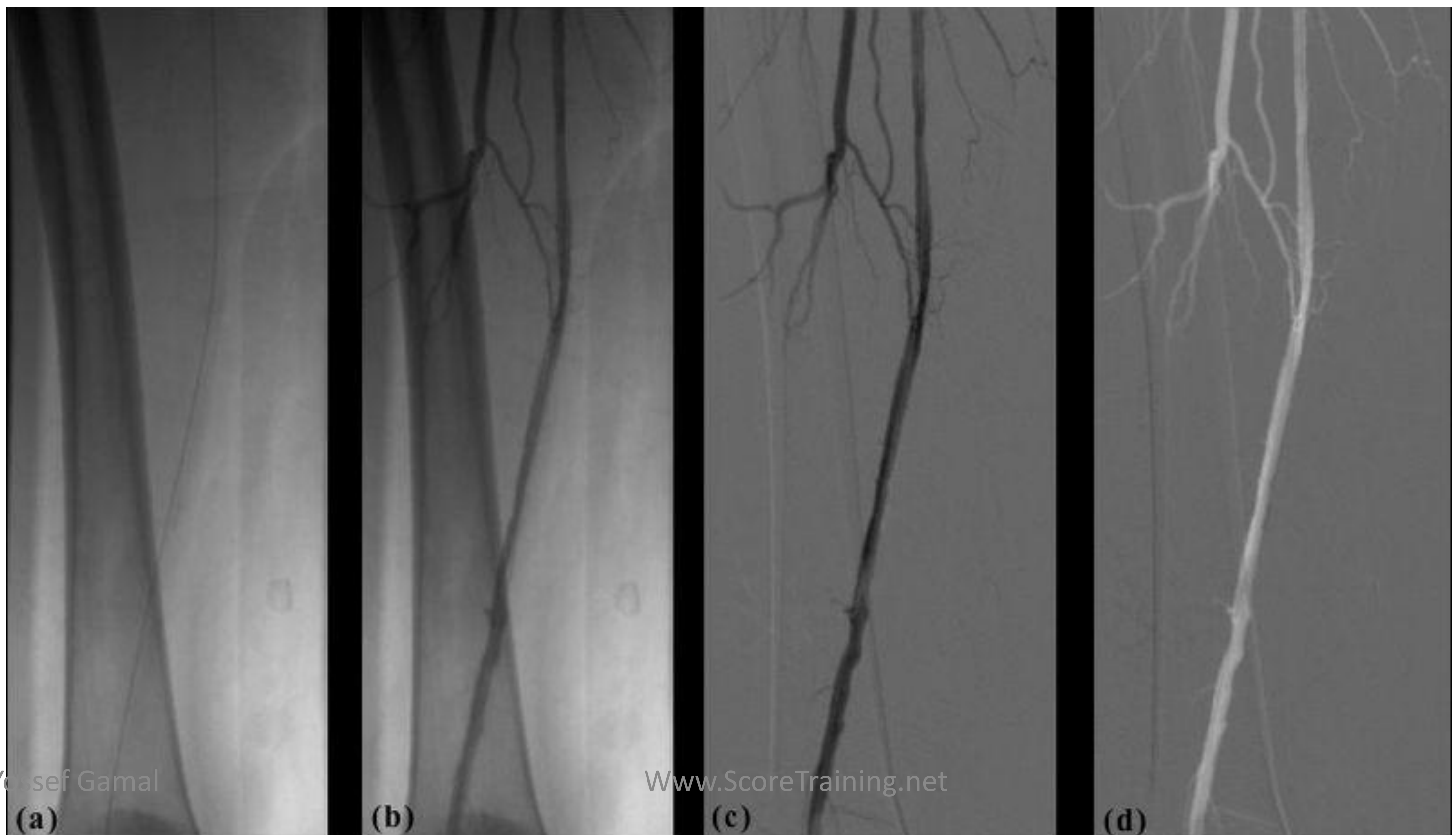
A) two non contrast images are taken (first : to stabilize x-ray factors , second: used as mask image (image A)

B) post-contrast image is taken (image B)

C) A is subtracted from B on a pixel to pixel basis → result in subtraction image C or D (shows the filled vessels only)

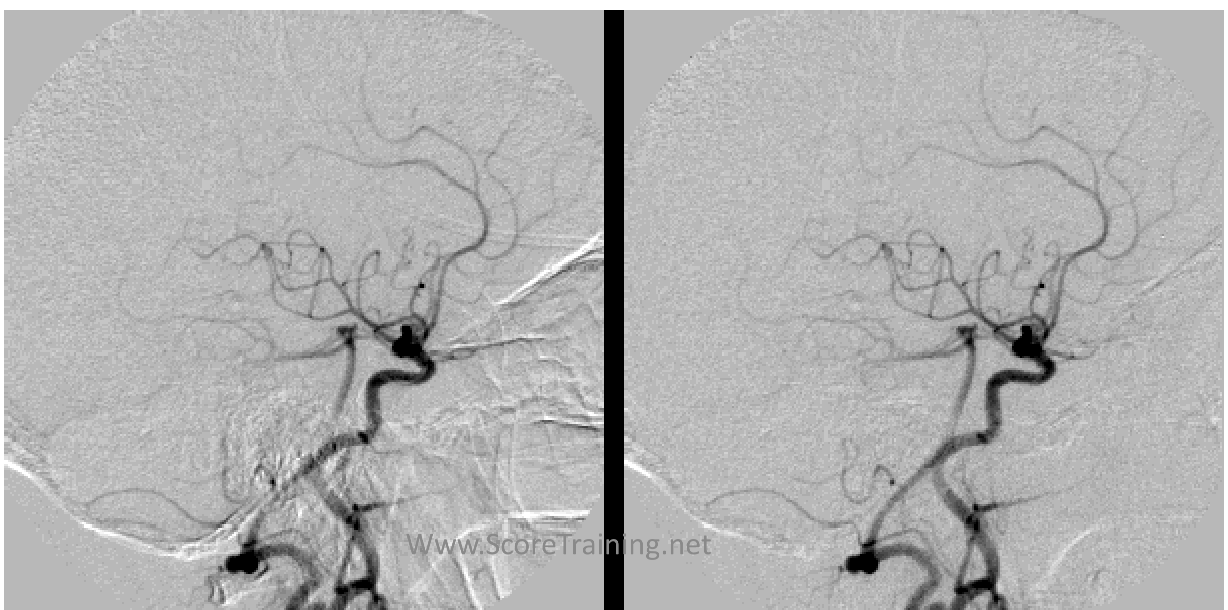
D) sequence of subtracted images can be recoded , based on the initial mask (and may be viewed in real time)

E) signals in the contrast and mask images are first converted to their logarithms before subtraction , and then are converted back into intensity values for display



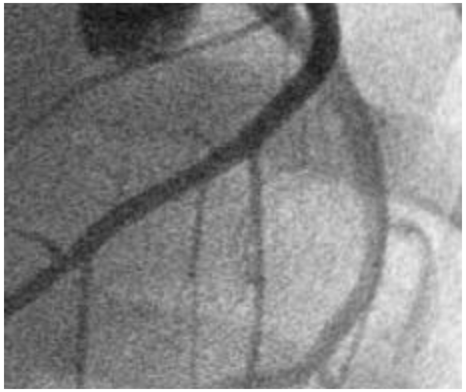
Problem(1): motion misregistration:

- *Cause:* movement between frames
- Particularly at boundaries between high contrast objects (e.g. at bone edges)
- *Solution:* pixel shifting:
  - retrospective adjustment of the mask image
  - This can be done only over the full area of the image (no differential movement within the field of view)
  - Can be done manually or using automated techniques

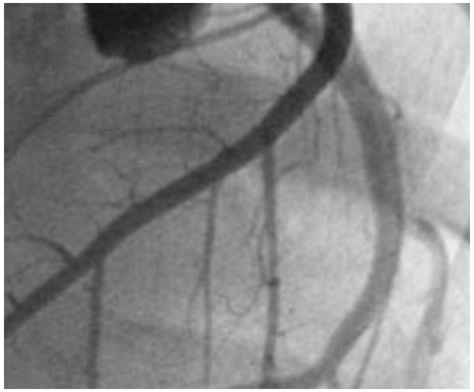


Problem (2): increased noise

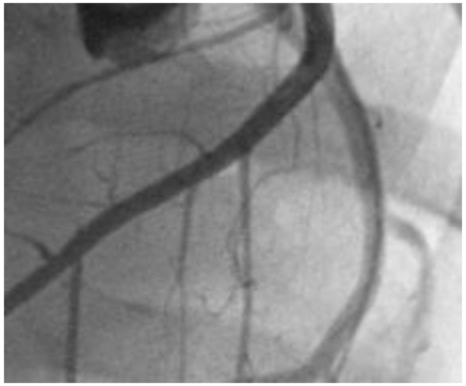
- *Cause :* subtraction cause that the number of pixels contributing to each pixel is decreased
- *Solution:* DSA requires increased mA



2 µGy per frame



15 µGy per frame



24 µGy per frame

Problem (3): length of anatomy imaged is usually greater than image intensifier field of view (e.g. lower limb angio)

- Solution (1):
  -several mask images are acquired
  -separate contrast administration for each region

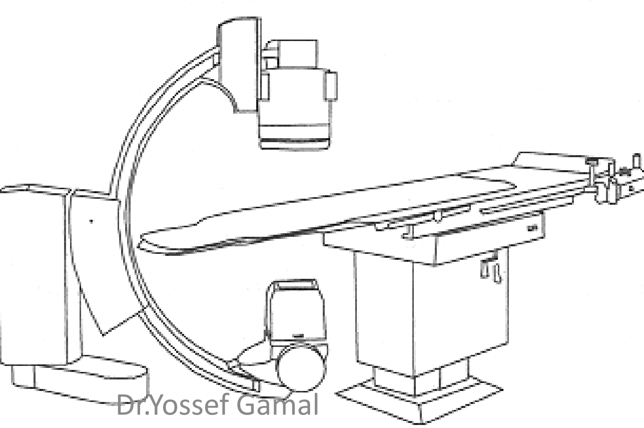
- Solution (2):
  – Several mask images are acquired
  – Single contrast image is acquired along the full leg length with longitudinal movement of the table to track the progress of contrast
  – Appropriate mask image for each table position is used in the subtraction
  – Advantage: ↓amount of contrast medium used
  – Disadvantages: increase likelihood of movement between mask and contrast images

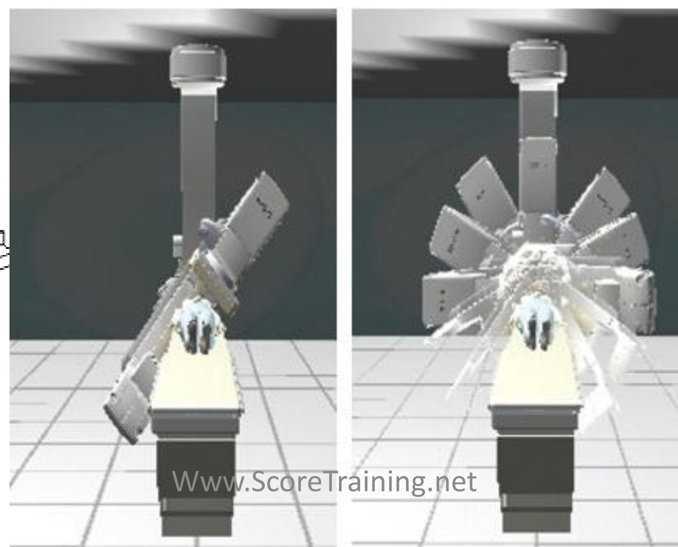
Rotational angiography

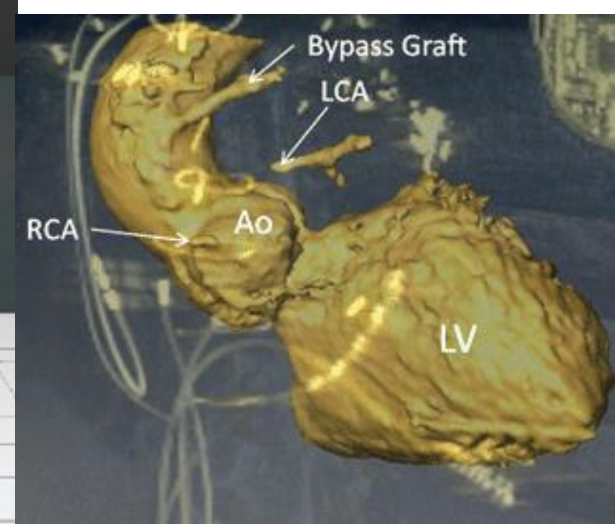
- 90º rotation x-ray tube and intensifier about the patient → mask images are taken at several angles
- Post-contrast images are acquired at the same angles
- DSA are produced at each angle
- Advantages:

1-identification of optimum angle to view the vessel

2- three dimensional reconstruction







Dual energy subtraction

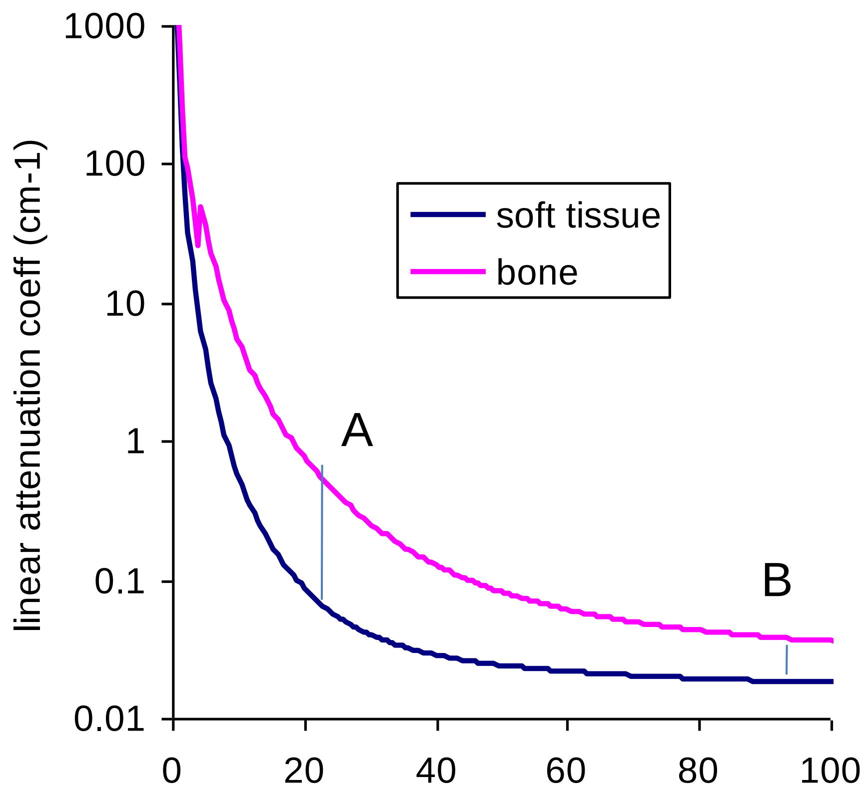
Dual energy subtraction

1) image A is taken at low Kv → high contrast between bone and soft tissue
2) image B is taken at high Kv → contrast is reduced
3) Subtraction process:
   – B – A → minimize visualization of bones and improves soft tissue contrast (e.g. chest x-ray to remove rib densities)
   – A – B → displays bony structures in greater details


Standard image

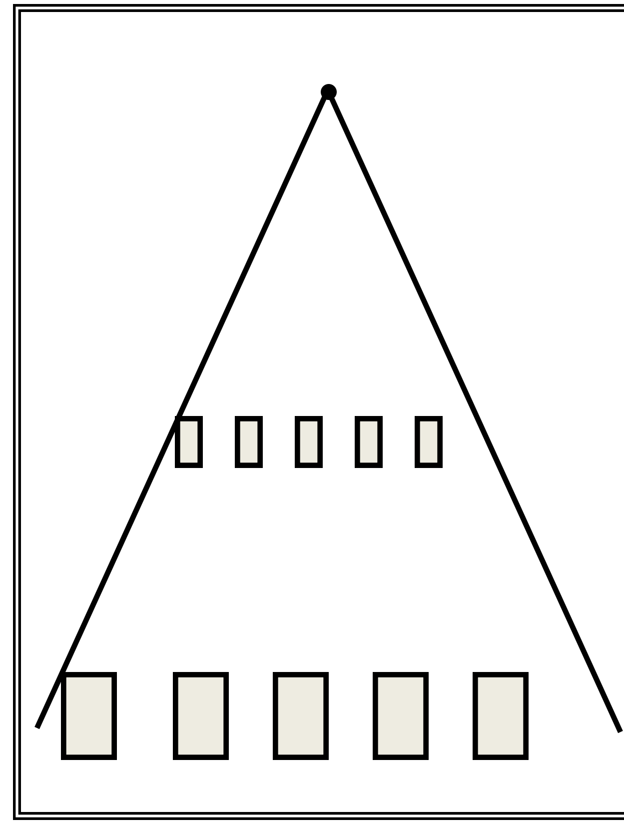

Soft tissue image


Bone image



Imaging Screen MTF

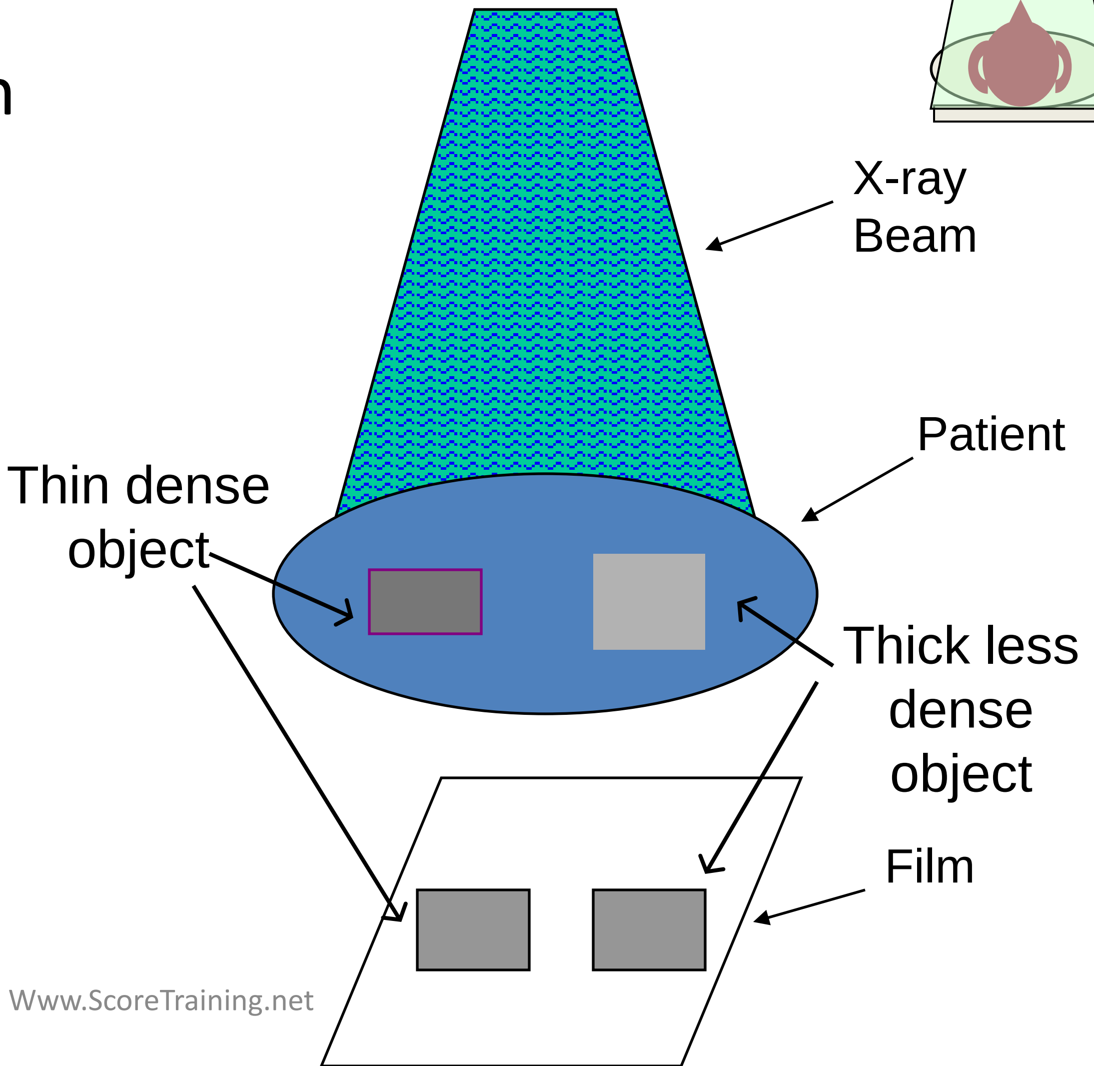
- <u>improves</u> with magnification
- Why?
  - magnification of an object of given frequency reduces frequency seen by screen

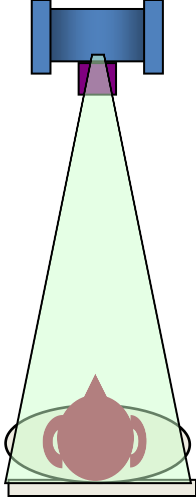


Computed tomography

Radiography vs. CT

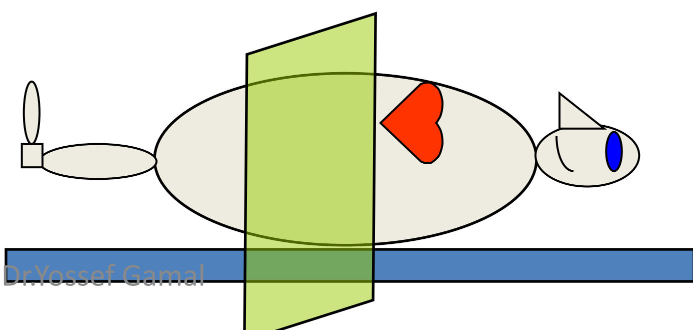
- Radiography
  - Structures are superimposed on film (Viewed through underlying / overlying structures)
  - Thin highly-attenuating objects appear to be same density as thicker low-attenuating object.

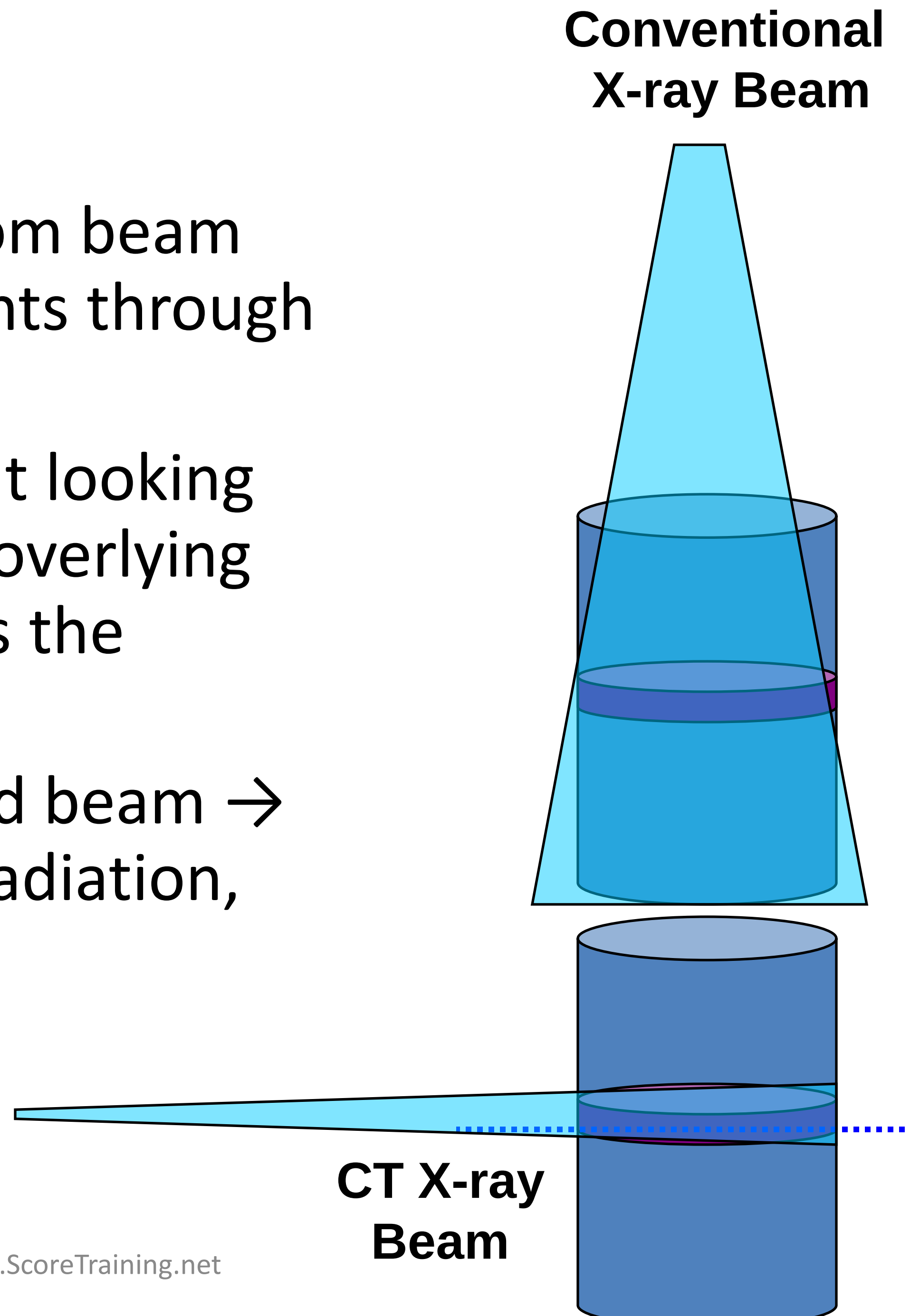




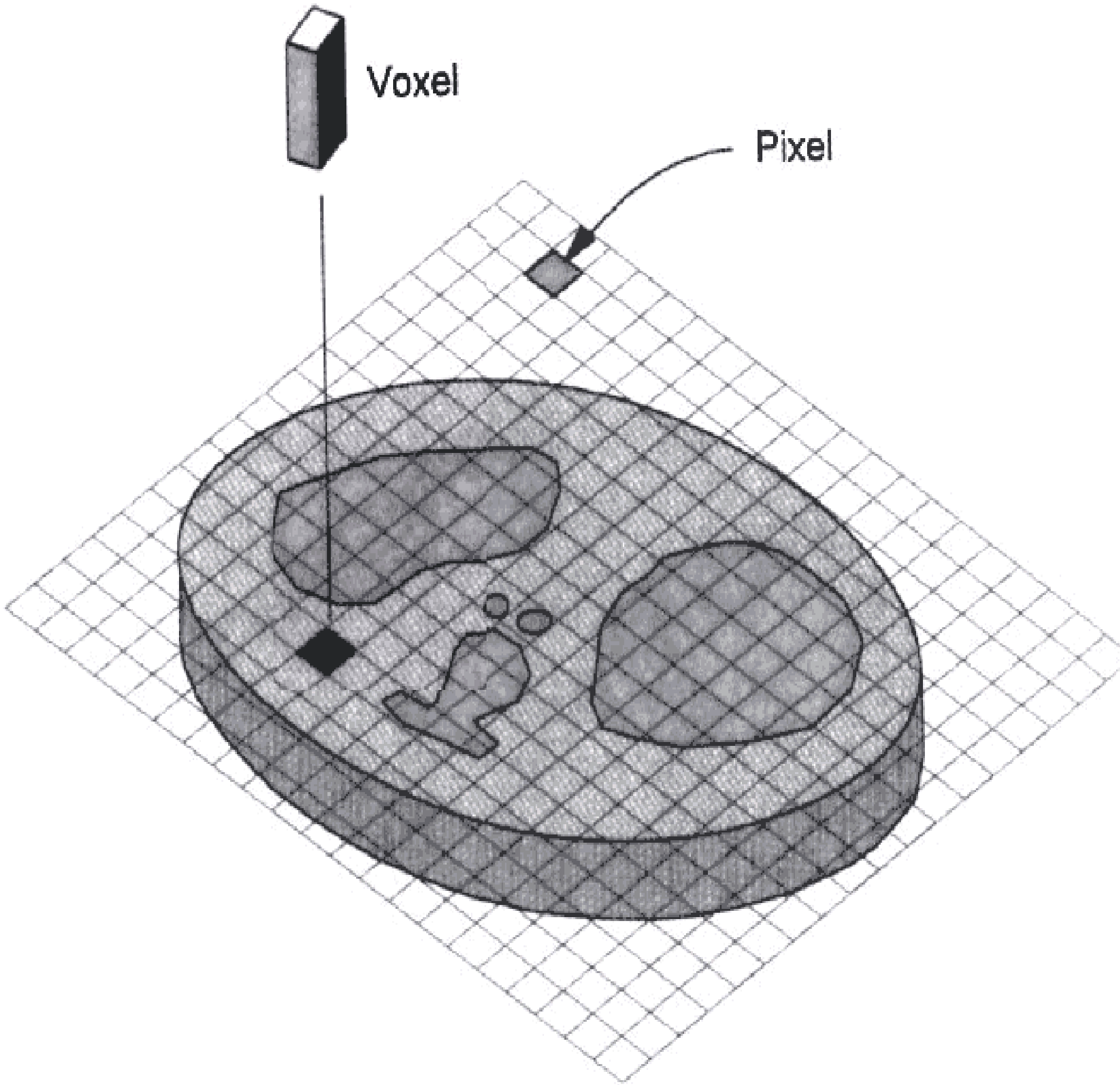
- CT
  - Cross-sectional image

  i.e. Image computed from beam intensity measurements through only slice of interest
  - View anatomy without looking through underlying / overlying structures→ improves the contrast
  - Uses tightly collimated beam → minimizes scattered radiation, improves contrast

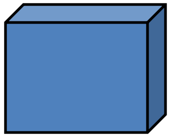


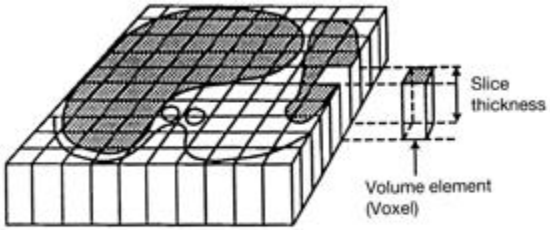


Pixels and Voxels



Pixels & Voxels

- Pixel is 2D component of an image 
- Voxel is 3D cube of anatomy 
- Voxel depth
  - same as slice thickness



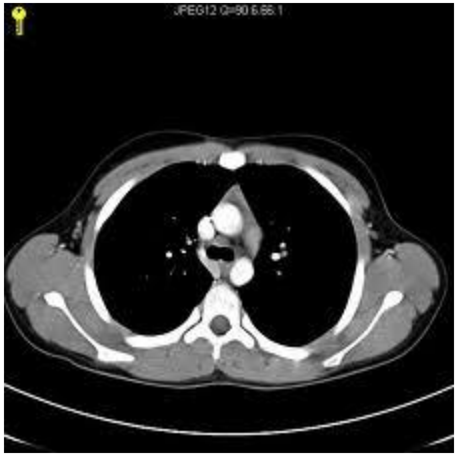
- CT reconstruction calculates attenuation coefficients of Voxels
- CT displays these attenuation coefficients as gray shades of Pixels

CT Number = Hounsfield Units

Determines the grade of gray which is displayed in each pixel

Depends on the attenuation coefficient of the voxel

$$CT\ \# = 1000 \times \frac{(\mu_t - \mu_W)}{\mu_W}$$



Where:
u_t = linear attenuation coefficient for tissue in voxel
u_W = linear attenuation coefficient for water

Example 1: voxel contains water ($u_t = u_w$):

CT# = 1000 x (μ_w - μ_w)/ μ_w = 0

Example: voxel contains air ($u_t \approx 0$):

CT# = 1000 x (0 - μ_w)/ μ_w = 1000 x (-1) = -1000

- Notes:

1- air and water are used for calibration of CT number scale of the scanner

2- CT number depends on μ of the tissue

i.e. depends on : Z, Density , kv used & filtration

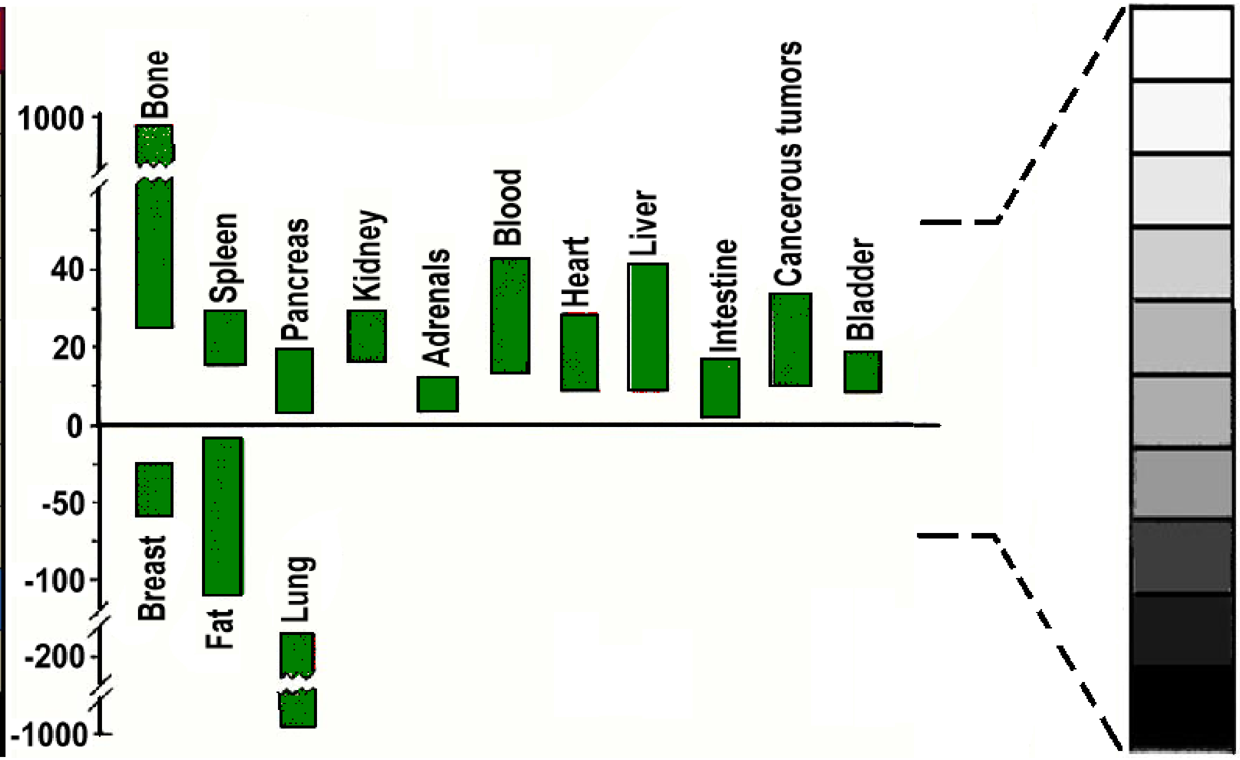
3- range of CT number values can be displayed is : -1024 to + 3071

Explanation:

Pixel depth of the CT scanners usually = 12

i.e. levels of gray displayed = 2^{12} = 4096

Tissue	CT Number (HU)
Bone	**+1000**
Liver	40-60
White mater	-20 to -30
Grey mater	-37 to -45
Blood	40
Muscle	10-40
Kidney	30
CSF	15
Water	**0**
Fat	-50 to -100
Air	-1000

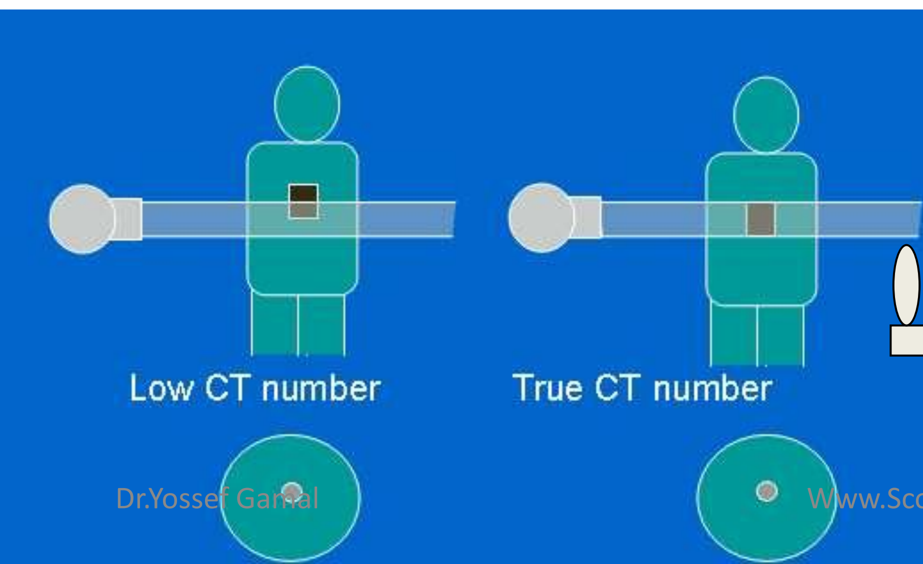


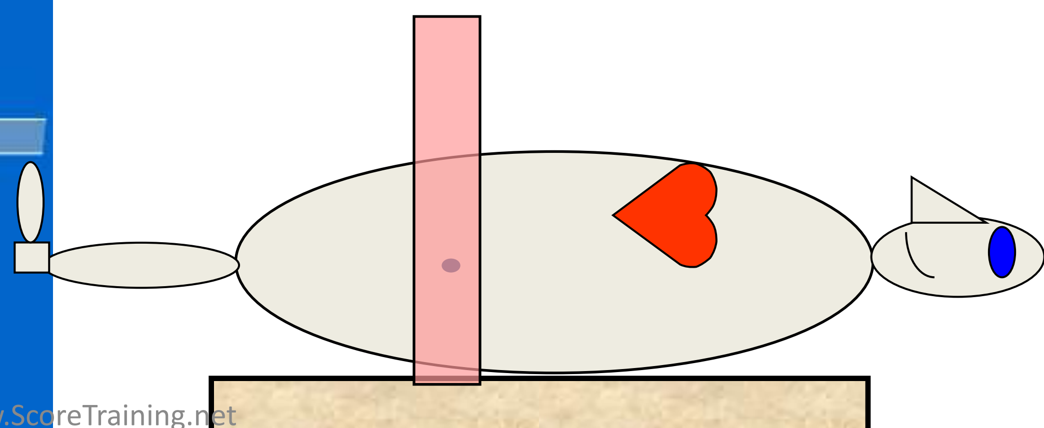
Volume averaging effect

- Cause: The CT number stored in each voxel represents average attenuation coefficient in the voxel
- Results:

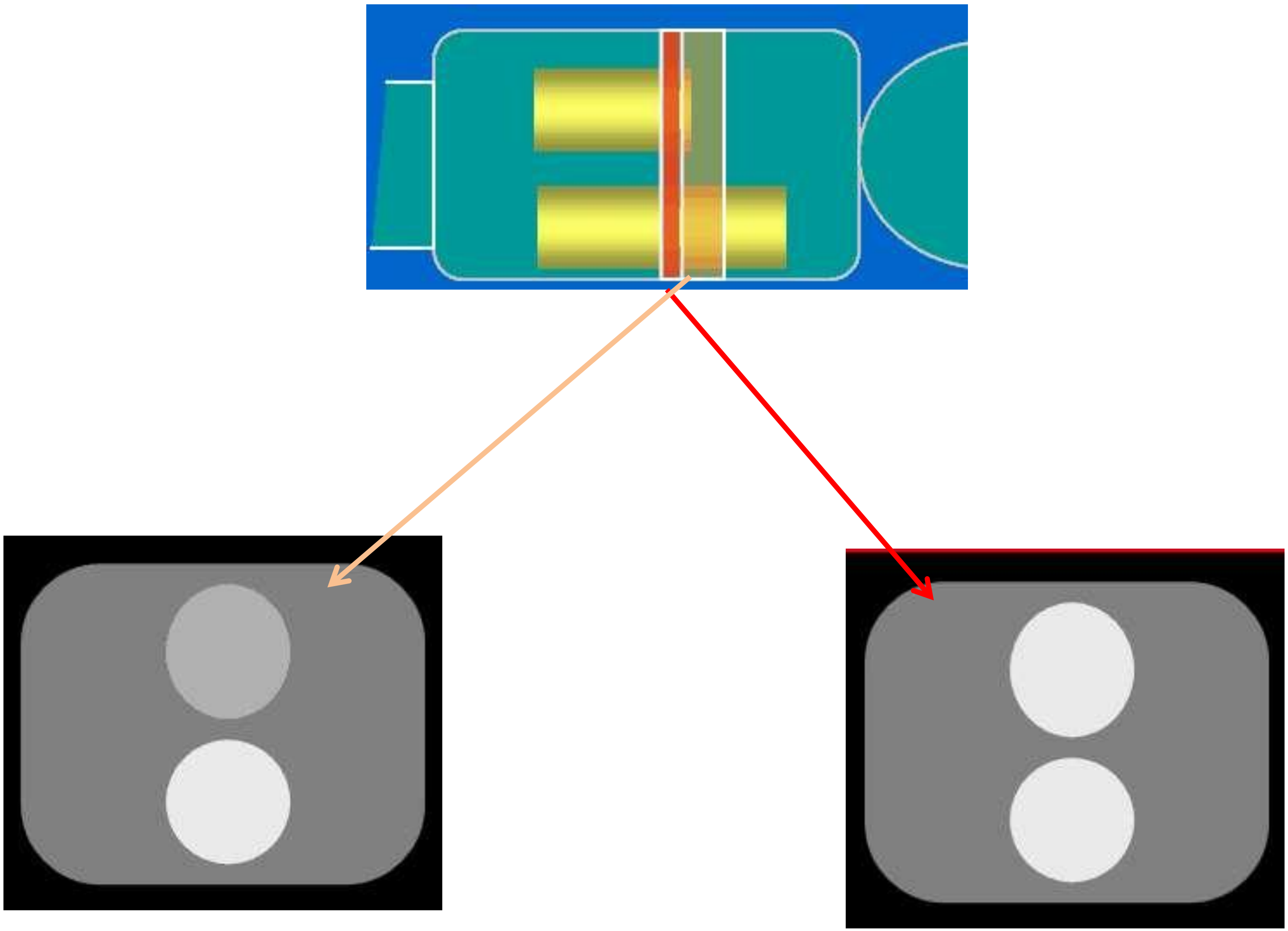
- High contrast object can be seen even if it is smaller than the pixel (small low contrast details will not be visualized)

-thin **high** contrast structure will be visualized larger than normal e.g. oblique enhanced vessel





Depends on: slice thickness : the thinner the slice, the less is the volume averaging

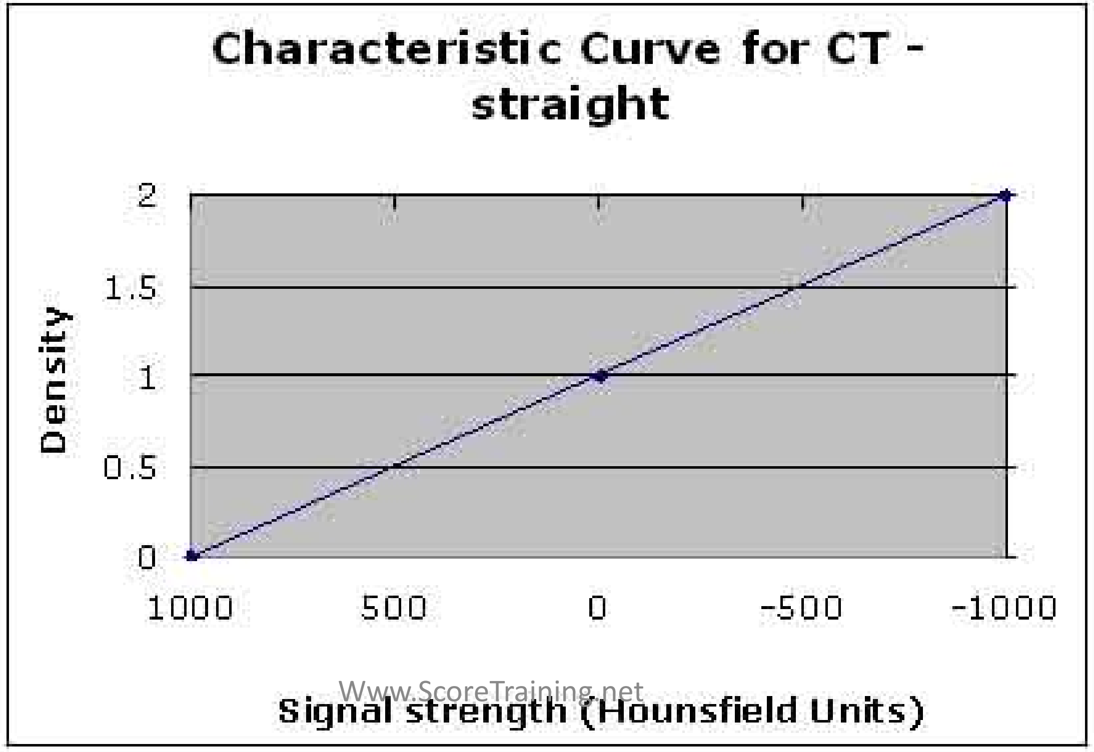


Display of CT (Window and level)

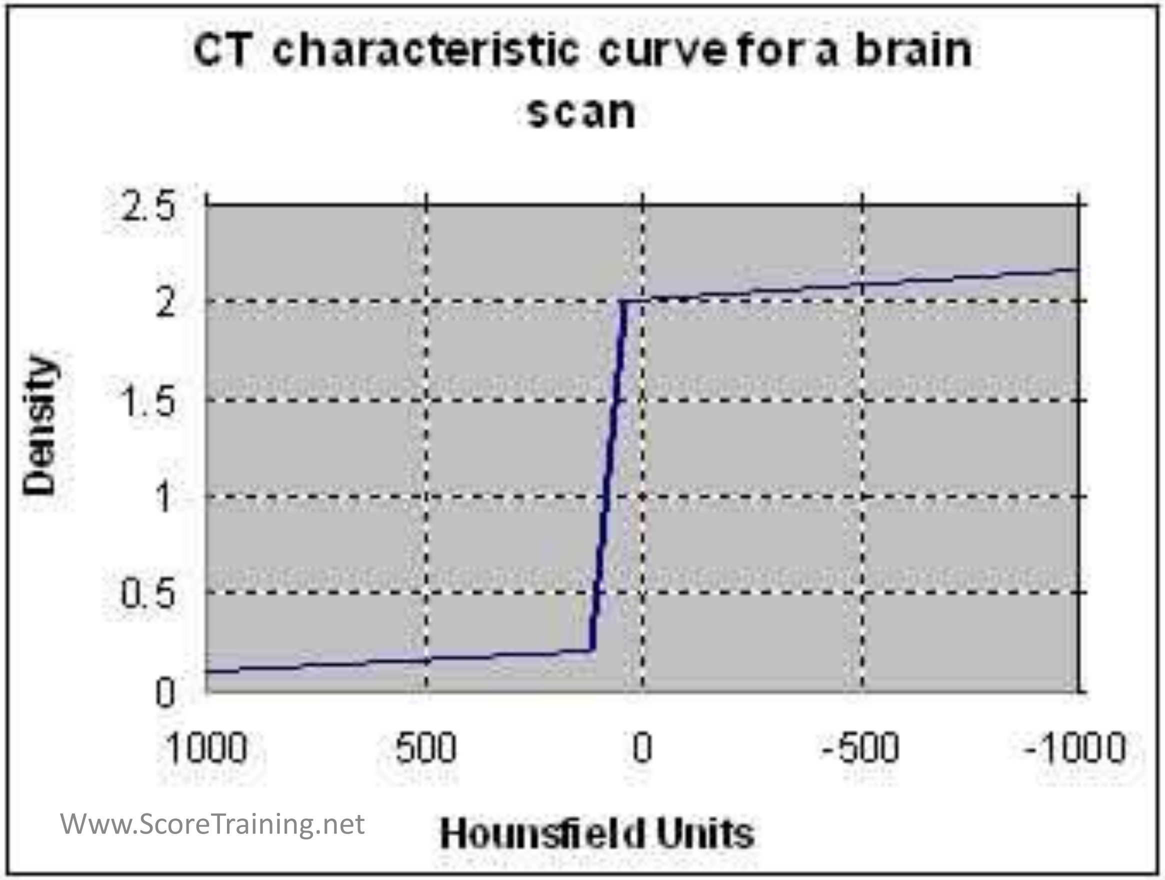
- Gray shade assigned to each pixel value (CT #)
- If the image displayed as such: image with very bad contrast (very high latitude)

47

93



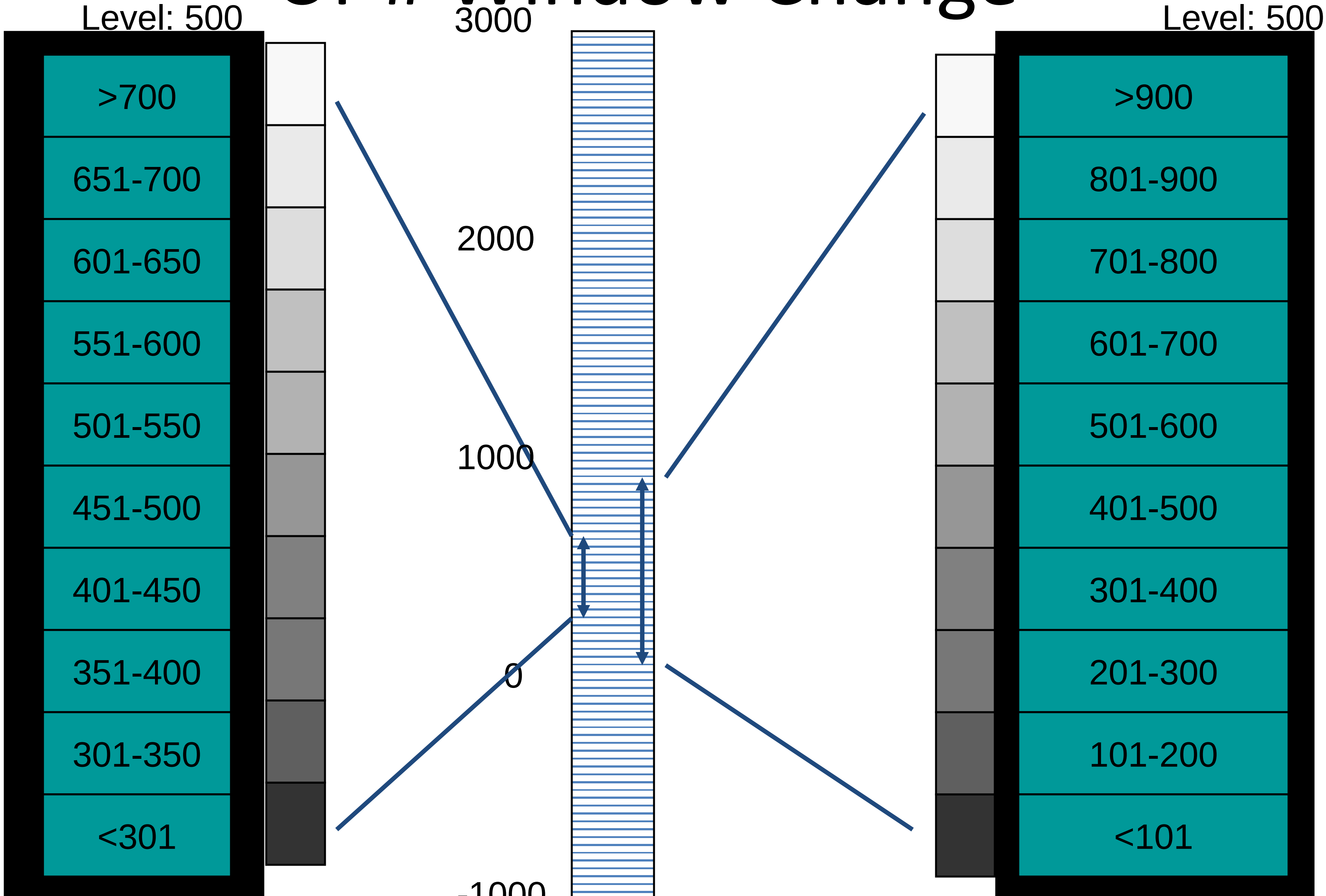
- Windowing:
  - Assignment of densities to pixel values according to clinical interest
  - does <u>not</u> disturb original pixel values in memory
  - Automatically or manually controllable
    - window
    - level



CT # Window Change

Window: 400
Level: 500

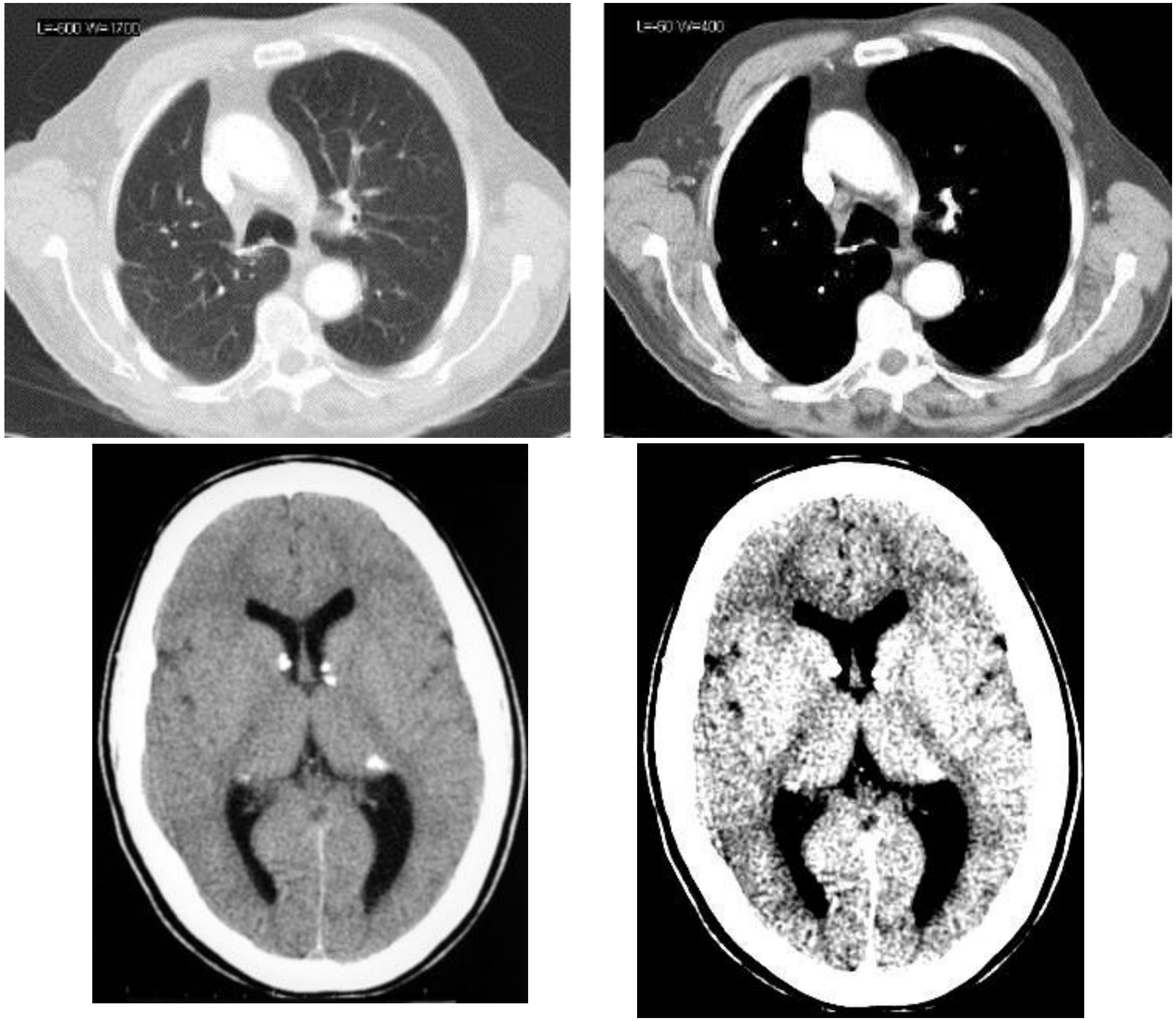
Window: 800
Level: 500



All pixels with HU <301 will appear black

All pixels with HU >900 will appear

CT Window Change

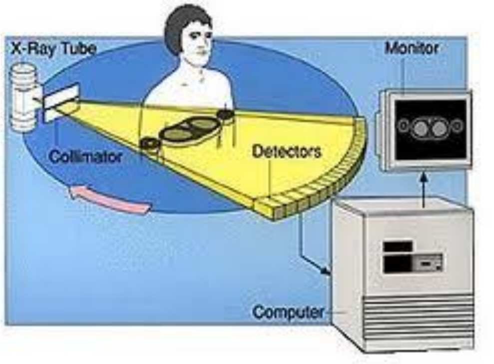


- *The narrower is window* width to the greater is the image *contrast and the greater is the ability to reveal low contrast structures*
- *The narrower is window* width to the less is the displayable latitude

CT equipment

CT components

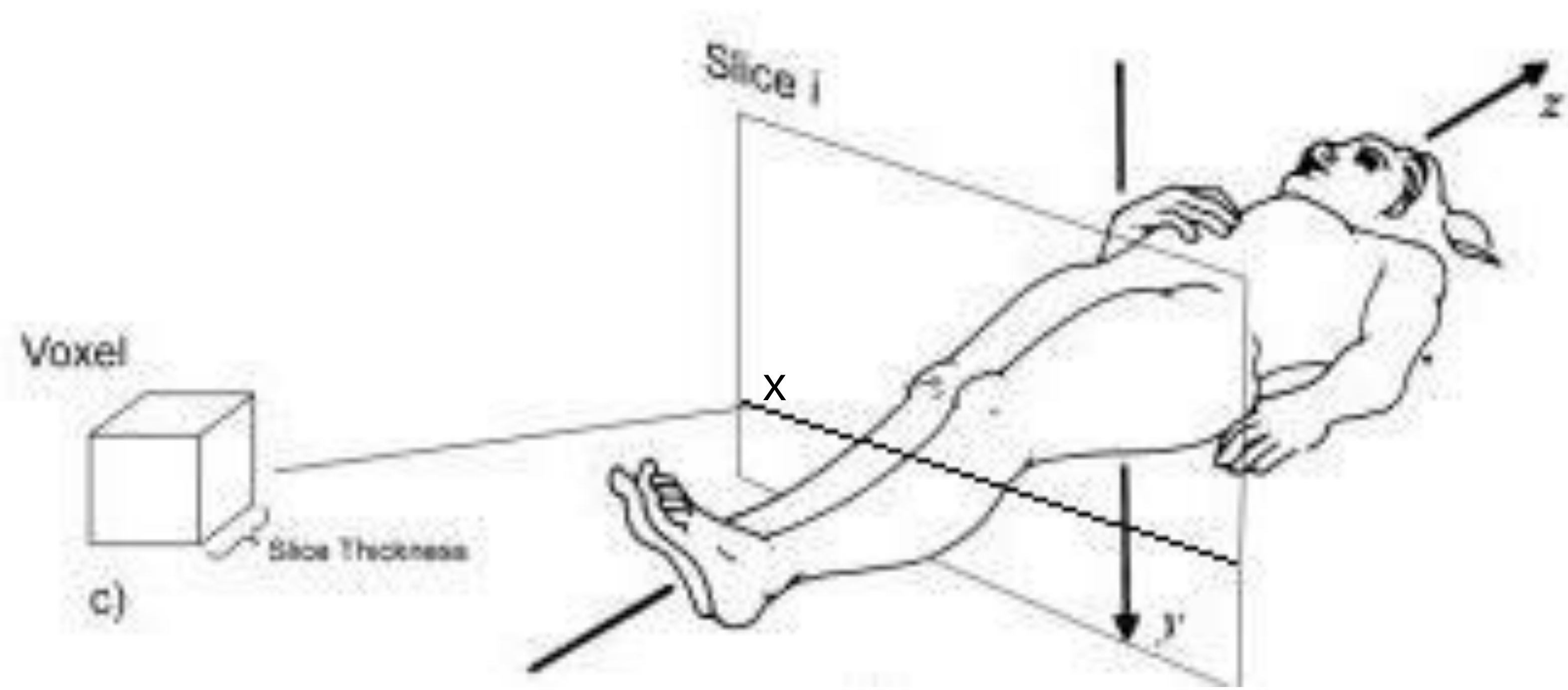
- gantry :
  - Provides structural framework for all other components
- Couch: Moving longitudinally
- x-ray tube : Produces x-rays
- Filters and Collimators
- Detectors



CT planes:

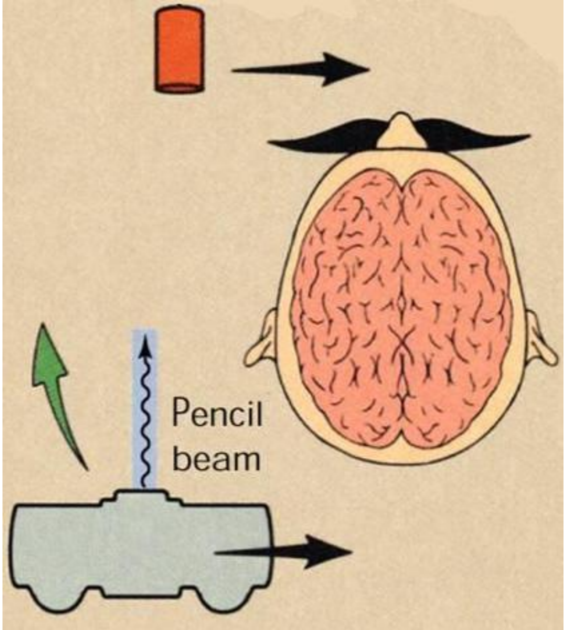
X and y = trans-axial plane

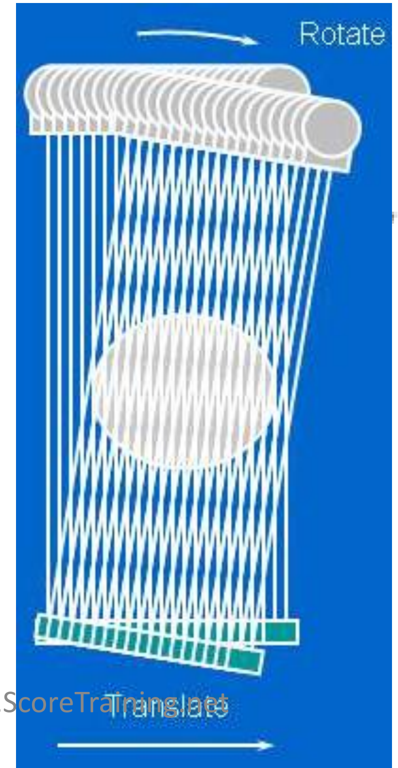
Z = longitudinal plane = plane of table movement

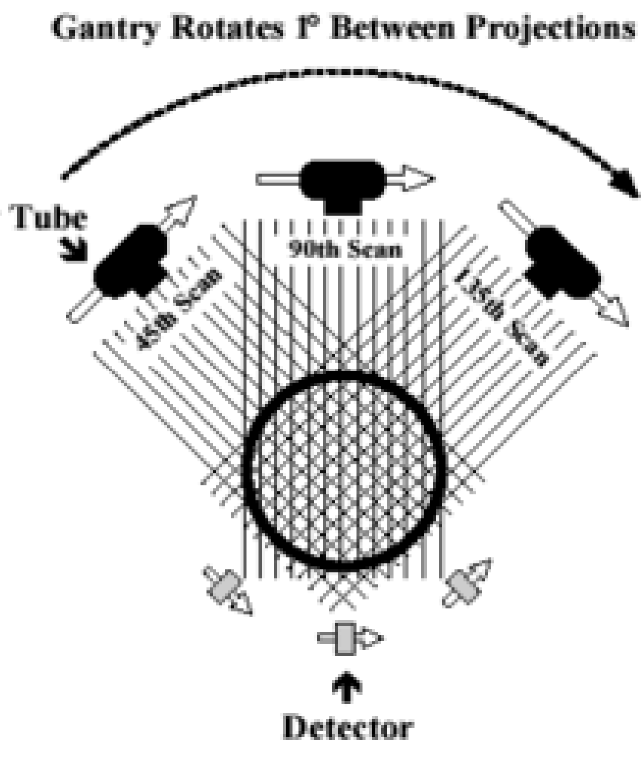


CT scanners generations

- First Generation Scanners
  - Formed of X-ray source and a single detector
  - Tube produce a pencil beam
  - Translation/Rotation type:
    - Translation: both tube and detector move across the scanning plane to acquire series of measurements
    - Rotation: then tube and detector is rotated by 1^{o} and process is repeated
  - 5 minutes to gather enough information for one slice
  - Tube was only able to rotate 180 degrees

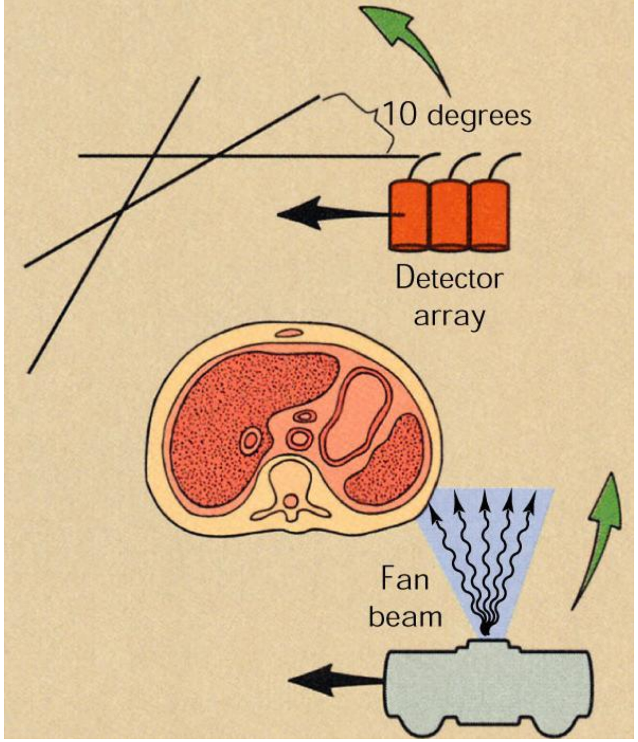


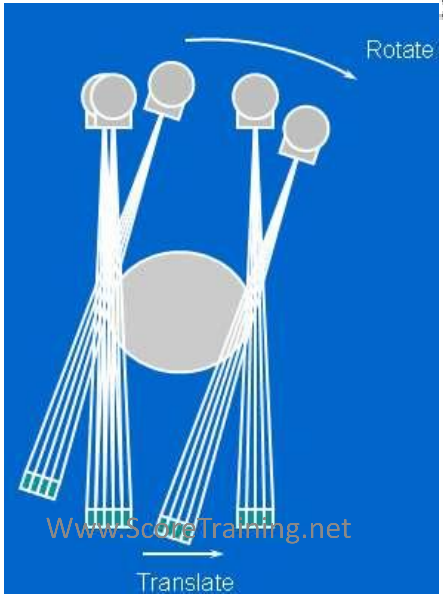


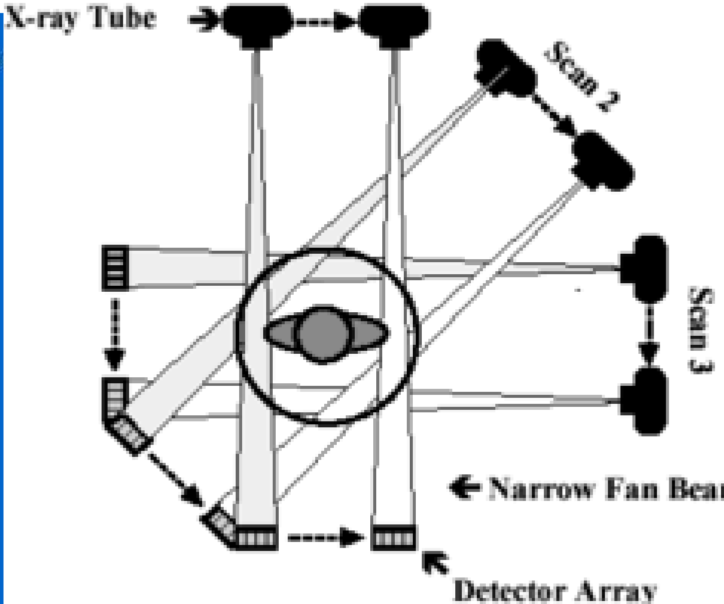


Second Generation

- Fan-shaped x-ray beam
- Bank of detectors (30 or more) , still insufficient to cover full cross section of the patient
- Rotation translation movement is still needed
- 20 seconds per slice
- 180 degree rotation



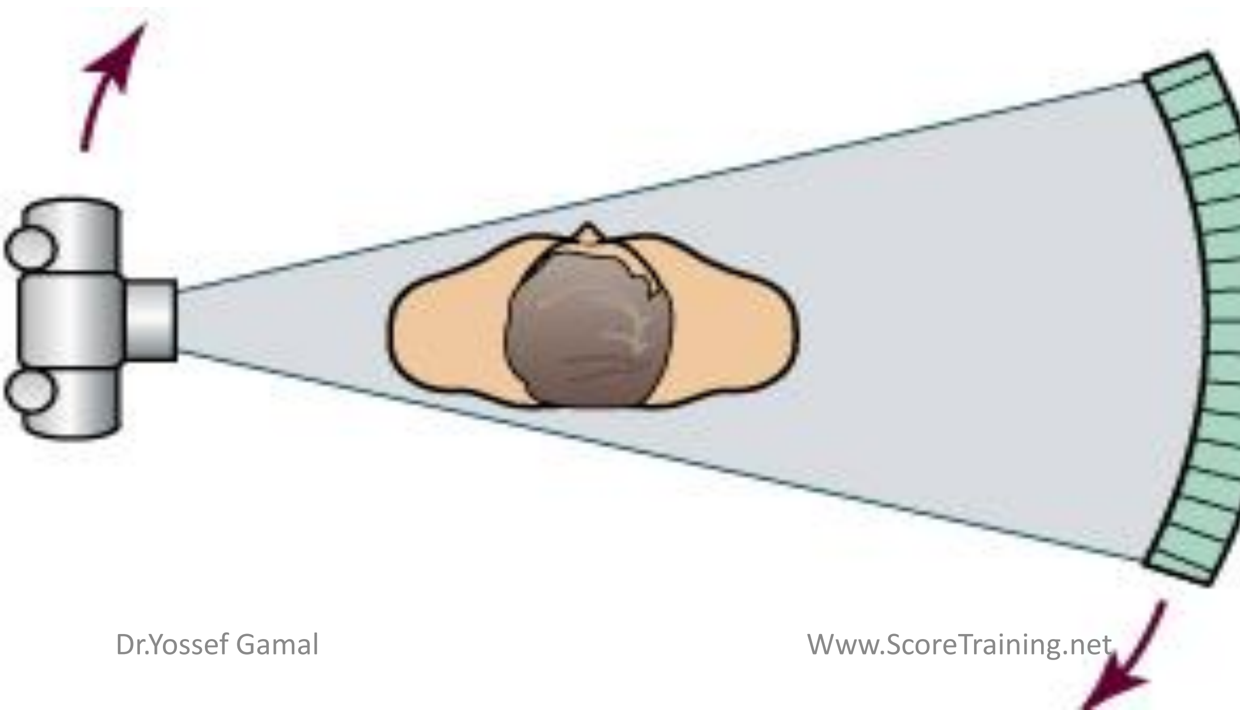


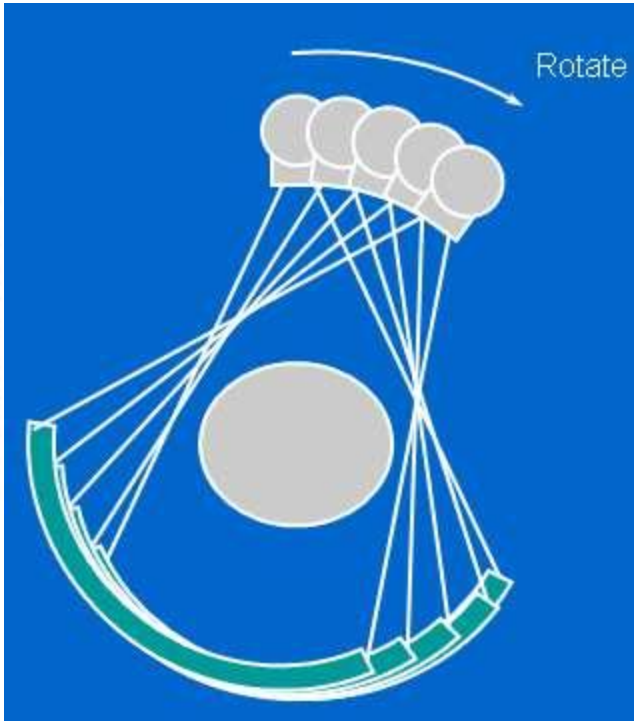


Dr.Yossef Gamal

Third Generation

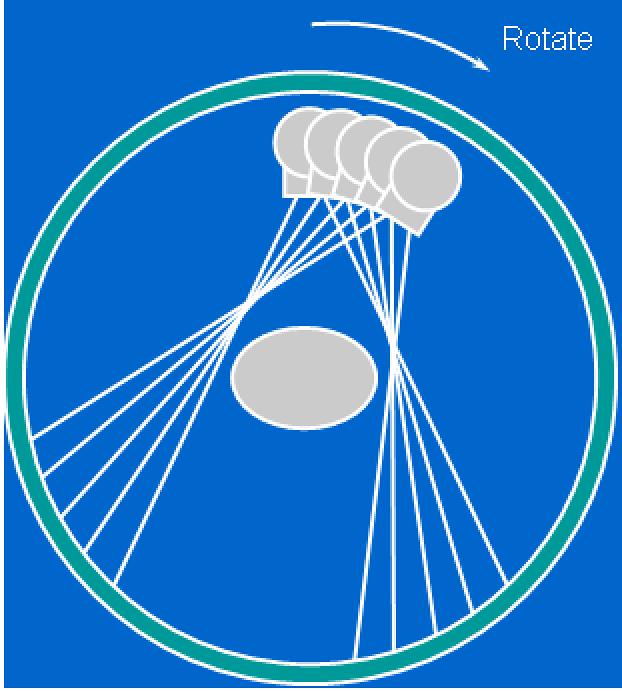
- Fan-shaped x-ray beam
- Large number of small detectors arranged in an arc to cover the full cross section of the patient → linear translation is not required
- Complete 360 degree rotation of tube and detectors
- Rotate/Rotate movement
- One rotation = one slice
- Time reduced to 1 sec per slice
- This type will be discussed in more details (Helical and multislice scanners are based on its idea)

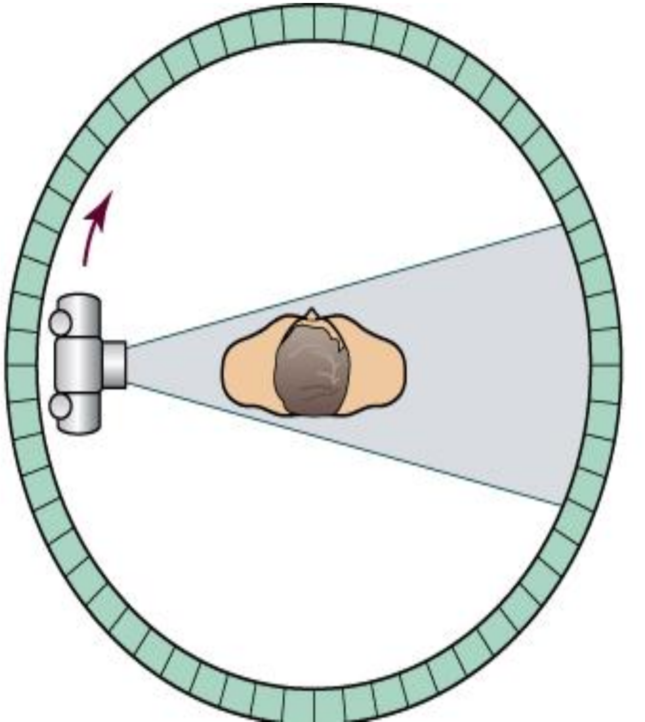




Fourth Generation

- Rotate – stationary scanner
- Rotating x-ray tube
- Detectors are arranged stationary ring completely surrounding the patient
- Advantages:
- More detectors stability
- Simpler reconstruction
- Outer part of fan beam always passes outside the patient → during each rotation every detector is able to measure the unattenuated beam → this measurement is used to adjust calibration throughout the scan
- Disadvantages:
- ↑ number of detectors (6 folds)
- ↑ dose due to ↑ distance between patient and detectors



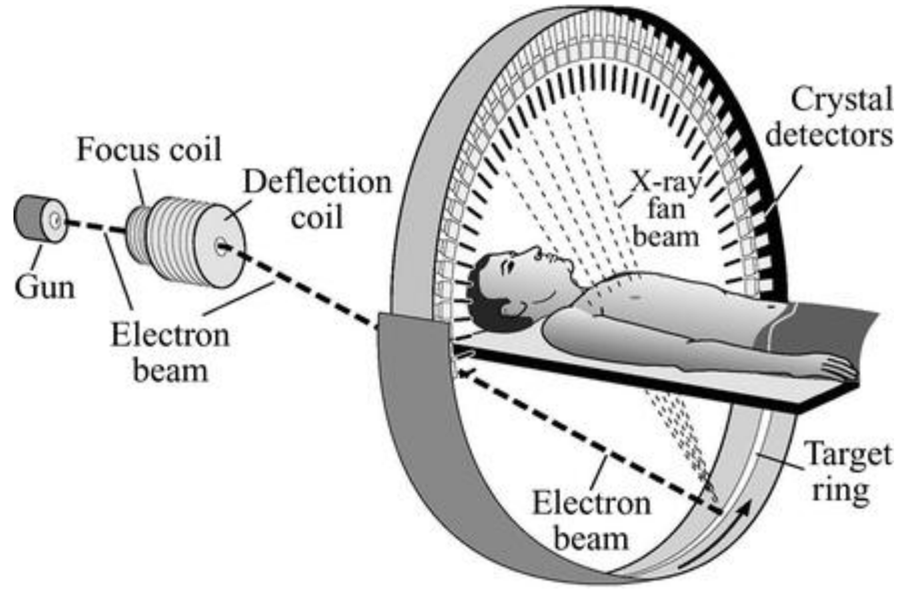


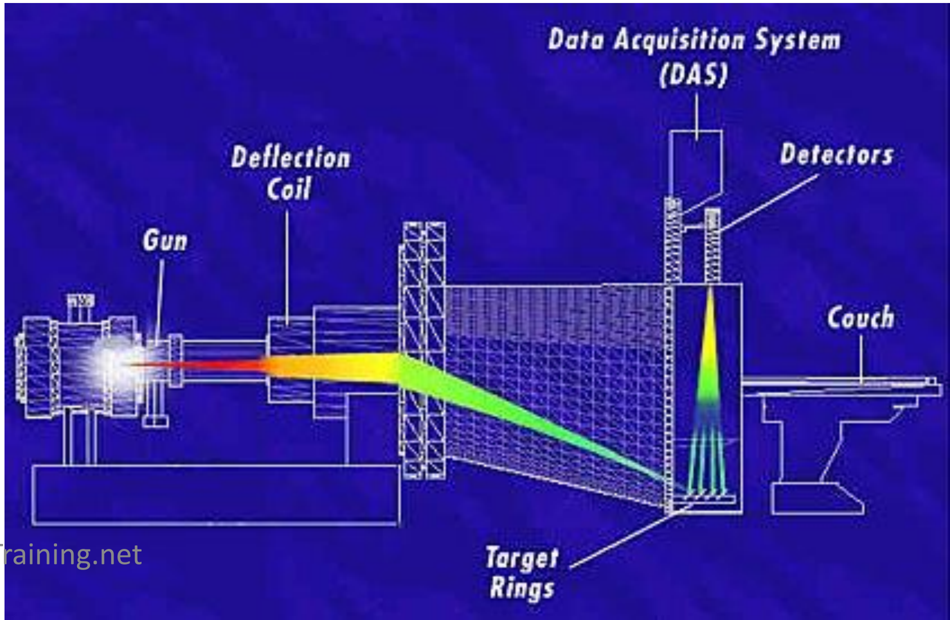
Fifth Generation = electron beam scanners

- Electron beam focused on target ring which cover 210^{o} arc around the patient
- →X-ray is produced & collimated and detected by detectors ring above the patient forming 216 ^{o} ring
- Advantage:

- No rotation of mechanical parts → electron beam is swept across the full arc in less than 50 ms. (slice time)

- Used in cardiology






Thank You!